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Environmental Security Technology Certification Program (ESTCP)

A Portable Burn Pan for the Disposal of Gun Propellants

Project ER-201323

Michael R. Walsh

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Abstract

Munitions for indirect fire weapon systems are issued with a full complement of propellant charges. Excess charges are typically not turned in and are destroyed by open burning as part of the unit's training. Burning of the charges can result in up to 20% of the propellant remaining in the form of residues on the ground. A portable propellant burn pan system was design and demonstrated as part of Environmental Security Technology Certification Program (ESTCP) Project ER-201323 to enable safe, environmentally effective training of the military. Tests have demonstrated a 99.98% reduction in combustible mass of the charges, less than 0.001% of the energetics in the burn pan ash, energetics concentration of less than 0.5% in the residual ash, and no detectable difference in energetics in the soil surrounding the pan after burning over 450 kg of charges. Performance objectives for the burn pan device were met or exceeded by the final system design. Costs associated with acquisition, implementation, use, and maintenance of the burn pan system are reasonable. The U.S. Army Cold Regions Research and Engineering Laboratory portable propellant burn pan training device has been enthusiastically accepted by all who have participated in the ER-210323 test and demonstration program.

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List of Acronyms

CGMI .... Camp Grayling, Michigan
CRREL .... Cold Regions Research and Engineering Laboratory
UHPLC-MS............ Ultra-High-Pressure Liquid Chromatography-Mass Spectrometer detector
ARNG(B) .... Army National Guard (Bureau)
HASP .... Health and Safety Plan
NG........................... Nitroglycerin
NQ........................... Nitroguanadine
NC........................... Nitrocellulose
AcN .... Acetonitrile
USARAK .... US Army Alaska
AEC......................... Army Environmental Command
AFB .... Air Force Base
AP .... Ammonium Perchlorate
ClO_4......................... Perchlorate
C-MIST .... CRREL Multi-Increment Sampling Tool
DAC......................... Defense Ammunition Center
DNT 2,4-Dinitrotoluene
DoD......................... US Department of Defense
DRDC...................... Defence Research and Development Canada-Valcartier
DTA......................... Donnelly Training Area, Alaska
EPA .... US Environmental Protection Agency
ESTCP..................... Environmental Science and Technology Certification Program
FIG.......................... Fort Indiantown Gap, PA
HPLC-UV................ High-Performance Liquid Chromatograpy-Ultra-Violet detector
JBER....................... Joint Base Elmendorf Richardson (AK)
MI .... Multi Increment®[1]
MIS .... Multi-Increment Sampling
MMR....................... Massachusetts Military Reservation
NG........................... Nitroglycerine
NQ........................... Nitroguanidine
Pb............................ Lead
RoI .... Return on Investment
SERDP .... Strategic Environmental Research and Development Program
SOP .... Standard Operating Procedure

[1] Multi Increment is a trademark of Envirostat, Inc.

Acknowledgements

Project ER-201323, A Portable Burn Pan for the Disposal of Gun Propellants, was a very successful project because of the involvement of a great many people. Dr. Bonnie Packer of the Army National Guard Bureau was essential in helping me get the project off the ground. She investigated potential test and demonstration sites, put me in contact with essential personnel at those sites, and “greased the skids” for me so that setting up tests was a lot easier than anticipated. Dr. Packer also fully embraced the concept, requesting background reports and papers as well as test reports from all the demonstrations, which she used to develop a Best Management Practices document on the use and benefits of the burn pan for the ARNG. She attended one of the demonstrations and provided valuable feedback on design improvements. I would also like to thank Mr. John Hunt, Environmental Officer, Camp Grayling, MI, and CPT. Patrick Rippeth and 1SG Scott Zaebst of the 1/134th OH ARNG; Ms Jo Anderson and LTC Mike Fluck, Fort Indiantown Gap, PA, and CPT Lawrence Fagan and SGM Ron Maraffi of the 110th INF PA ARNG; and MS Ellen Clark, Mr. Steve Thurmaon, and Mr. Derek Mills, Donnelly Training Area, AK, and CPT Nelson Liuzzo and SSG Emmanuel Rodelo of the 2/377th PFAR, 4th BCT/25th ID. These are the people and soldiers on site that, through their assistance and participation, allowed the tests and demonstrations to be successful.

There were many highly skilled and dedicated personnel at CRREL who were also key to the project’s success. Marianne Walsh and Matt Bigl were indispensable to the project, involved in the test design, test setup, sample collection, and analyses of the samples collected for the tests. Charlie Smith, Andy Bernier, Tommie Hall, Jordan Hodge, Stacey Jarvis, and Sam Beal were also essential field personnel over the life of the project, assisting in the field tests in many ways. Chris Donnelly did a fantastic job in CRREL’s machine shop building the burn pans for both this project and for SERDP ER-1481. Jordan Hodge assisted Chris in the shop and also provided the drawings for the various incarnations of the pans.

I also thank Dr. Andrea Leeson and Deanne Rider of ESTCP’s Environmental Restoration Program for their administrative assistance and encouragement over the course of the project. We all appreciate ESTCP’s support for our work.

Executive Summary

Training with munitions will result in the deposition of energetics on ranges. Artillery training with mortars and howitzers adds a unique component to potential range contamination. Munitions are issued with a full complement of propellant charges that are varied according to the state of the equipment and mission. Excess propellant is burned on site as part of the training mission. Research under SERDP ER-1481 established that up to 20% of the propellant in these burns may not burn properly or at all, contaminating the burn point where the training occurred. The US Army Cold Regions Research and Engineering Laboratory developed and tested a prototype portable burn pan under SERDP that enabled artillery batteries to conduct training burns while minimizing the environmental impact of the activity. Through ESTCP ER-201323, the portable burn pan concept has been refined, tested, and demonstrated to both the Army and the Army National Guard.

Two types of portable propellant burn pans have been successfully tested during this project. The designs for the pans have been finalized, one design for mortar training units and a larger one for artillery training units. The pans are designed with user input from the training units, range managers, and range environmental staff. The pans are easy to use, have a quick turnaround, minimize residual energetics and combustible mass during burn training, can be cleaned easily, and provide a tool to conduct safe, environmentally friendly training for units. Tests have demonstrated a 99.98% reduction in combustible mass of the charges, less than 0.001% of the energetics in the burn pan ash, energetics concentration of less than 0.5% in the residual ash, and no detectable difference in energetics in the soil surrounding the pan after burning over 450 kg of charges. All performance objectives for the burn pan device were met or exceeded by the final system design.

Costs associated with acquisition, implementation, use, and maintenance of the burn pan system are reasonable. The cost per unit on a single-build basis was around $10K. Fabrication of multiple units will bring the cost per unit down. There are no specific implementation costs. A pan easily fits in a small shipping container, where it can be secured. The pan costs nothing to operate, and periodic maintenance is low. Following the propellant burn training, the ash can be scooped out and bagged for disposal.

Contaminant levels in the ash are quite low and the material can be disposed of without special handling, although we recommend disposal through the hazardous waste route, especially if some of the propellant charges contained lead. A per-year operating cost for the burn pan system should be less than $5K/yr. Environmental liabilities related to propellant constituents such as nitroglycerin, dinitrotoluene, and perchlorates can run into the tens of millions per year at sites with contaminated surface water, soil, and groundwater.

The CRREL portable propellant burn pan training device has been enthusiastically accepted by all who have participated in the ER-210323 test and demonstration program. Range and Environmental officials at all three installations not only asked to keep the burn pans tested on their ranges but asked if they could acquire additional units. The training units also have enthusiastically embraced the concept, with soldiers and officers all asking if they could continue using the burn pans after the completion of the demonstrations. The burn pans have been integrated into the SOPs of all three installations and the Army National Guard Bureau has issued a Best Management Practices guidance document on using the burn pan at all installations that conduct artillery training.

1.0 Introduction

Live-fire training is an integral part of military preparedness for our armed forces. The firing of munitions, whether live or practice rounds, results in the expenditure of propellants. When training with artillery systems, munitions are issued with a full complement of propellant charges. These charges are never fully utilized and cannot be returned to the ammunition supply point following completion of the training exercise. This propellant is destroyed in one of two ways: By burning at a remote disposal site or by expedient burning at the training site. In many cases, the excess propellant is burned on the ground at the firing points, allowing the soldiers to "train as you fight." This is an inefficient process and may result in significant quantities of energetic compound and fine lead residues at firing points. To address this point source contamination problem while allowing troops to continue training as they fight, we have designed a portable burn pan for the disposal of excess gun propellants.

1.1 Background

The investigation of excess propellant burns began as part of a US Army Alaska (USARAK) –funded project to characterize soil contamination on their ranges at Donnelly Training Area outside Fort Greely in central Alaska. One of the areas sampled was an observation point (OP-7) that had a fixed burn for the disposal of excess artillery propellants located on it. This pan was in poor repair, rusted though in the corners, and propellant grains were scattered on the ground surface around the pan. Sampling of the soil around the pan revealed very high concentrations of 2,4-dinitrotoluene(DNT), a Class-2 carcinogen (35 mg/kg); nitroglycerine (NG), a toxic compound (6.4 mg/kg); and lead (5,300 mg/kg). The lead was in very fine particles, easily resuspended in the dry, dusty conditions at the site **[1] [2]**. Earlier tests conducted at Camp Grayling, MI, had lead levels in the soil of 5,100 mg/kg and 48 mg/kg of DNT adjacent to a fixed location burn pan **[3] [4]**.

Research funded under SERDP Project ER-1481 investigated residues from the direct burn of propellants on the ground. Experiments were conducted on various soil types and on snow in both Canada and the US to determine residues rates for the burning of different propellants. Up to 18% of the NG remained after burns conducted on snow **[1]**. Propellant grains

were also found in significant quantities in areas propellants had been expediently burned. In some locations, the propellants had actually been blown up rather than burned, resulting in very high contamination rates over a wide area. Both DRDC and CRREL realized there was a need for an improved burn pan system. In Canada, the thrust was directed towards a fixed disposal pan, to which excess propellants would be brought for disposal. In the US, we directed our efforts towards a portable pan that can be transported to the firing point where expedient disposal can take place as part of the training exercise. As ER-1481 came to a close, the Canadian Defence Forces implemented the fixed burn pan as part of their standard operating procedure **[5]**. In the US, two prototype pans were built and one tested as part of a training exercise in Alaska. A third prototype was designed but never built or tested.

1.2 Objective of the demonstration

The main objectives of the project demonstration are to validate the portable burn pan technology and to transfer the technology to the end users. Validation will be through a series of test burns at different facilities. Data will be collected during the burn, such as temperature of the burn pan unit, time to cycle through a burn, and working capacity of the pan. Samples will be taken to determine ejected residues mass and the mass of the ejected constituents of concern. Reduction of mass measurements will be taken to determine the mass reduction efficiency of the pans. When quantitative project goals have been met, the parameters associated with those goals will no longer necessarily be monitored.

Tech transfer will be done through several avenues. First, we will work through various agencies to present our concept for review. This has already been started with the Army National Guard Bureau. To encourage site availability, use of the pan, and user feedback, the prototype burn pans will remain at the facilities where the tests are conducted. Tech transfer will also occur by interfacing with potential users at venues such as the SERDP/ESTCP workshop and through connections with the range management community.

1.3 Regulatory drivers

The disposal of excess propellants is not conducted under any overarching regulation. States may have their own statutes or regulations guiding

practices. For instance, the State of Michigan ARNG Commanding General developed a standard operating procedure in 2008 following the investigation of the soils surrounding a burn pan detailed above [6]. In Alaska, local guidance has been issued by US Army Alaska that permits burning of excess artillery propellant at the training site, but encourages the use of fixed burn pans [7] [8]. Chapter 3, paragraph B1a of DoD Policy to Implement the EPA Military Munitions Rule [9] states that procedures for the open burning of unused propellant charges is a "required element of training and not a waste management activity." Thus, on-site burning of excess propellant charges is not considered a waste disposal action and is not covered by the regulations that govern a fixed waste disposal site such as a fixed burn pan. Federal regulations apply to some of the constituents found in propellants, including NG, DNT, and ammonium perchlorate, so control of residues containing these compounds is quite important for range sustainment. Thus, although regulations state that field expedient burning of excess propellant is not a waste disposal activity, the residues generated by this activity are covered.

Additional regulatory drivers for an optimized sampling design are the concentrations of 2,4-DNT and nitroglycerin (NG) in soil that may pose a risk to human health and the environment. Estimates of these concentrations (see **Table 1**) were derived under previous Strategic Environmental Research and Development Program (SERDP) projects concerned with environmental assessments and sustainability of training lands.

Table 1. Concentrations (mg/kg) of 2.4-DNT and NG that may be used in environmental assessments of military training ranges.

	Military-Specific Environmental Sustainability Indices (Canada)[a]		Soil Screening Concentration		Ecotoxicological Tolerance Values
Contaminant of Concern	*Human*[1]	*Ecological*[2]	*Biological Activity*	*Terrestrial Plants*	*Soil Invertebrates*
2,4-DNT	0.14	11	104[4]	6–13[3]	20–23[3]
NG	2500	65	114[4]	21[4]	13[4]

[1]Exposure based on soldiers spending 100 days in the field per year.
[2]Based on toxicological data and trophic models for microbes, plants, invertebrates, birds and grazing
herbivores.
[3]Sunahara et al. 2009 [10]
[4]Kuperman et al. 2011 [11]

2.0 Technology

2.1 Technology description

The technology to meet these objectives is a portable burn pan for the expedient field disposal of excess howitzer and mortar propellants. The portable burn pan was designed for simplicity, ease of maintenance, and ease of use. The pan in its current configuration is approximately 1-m wide by 2-m long. It has evolved over the last seven years, the original prototype pan and the second prototype built and tested under SERDP ER-1481. (**Fig. 1**)

First prototype: All stainless steel (2010) Second prototype: Aluminum base (2011)

Figure 1. Pre-ESTCP portable burn pan prototypes

The system is composed of only three parts, an aluminum base, a stainless steel false bottom, and a removable bonnet that fits on top of the pan (**Fig. 2**). The base elevates the system off the ground, providing both clearance from most combustible materials or snow that may lie beneath it while partially containing the burn. The base contains a removable stainless steel false bottom that protects the structure from the high heat of deflagration. The base and false bottom combination provides a dry, semi-enclosed platform that will separate the burning propellant charges from the ground surface and contain the hazardous debris from the propellant burn (ash) for easy removal and treatment. A removable, retractable ignition trough passes through the pan and extends into the false bottom to enable safe initiation of the propellant burn. The perforated bonnet partially contains the burn, limiting ejection of large unburned material such as charge bags that loft during the deflagration process. The perforated sides of the bonnet prevent a chimney effect that would loft propellant grains out of

the pan and into the environment, and an expanded stainless steel mesh tops catches the larger lofted material in the flame. The charge debris is thus contained within the burn zone. The device is compact enough to transport in a standard small military truck and light enough to be handled by four or fewer personnel. The target propellant charge load is in the 120 kg range for a full-size burn pan, although we recommend limiting the charge load to 90 kg if there is vegetation nearby. The portable device can be transported to the training site, enabling troops to burn excess propellant following training without having to transport the charges to a central burn facility, thus reducing transportation hazards. The loading dimensions of the false bottom of the pan are 0.9 x 1.9 m.

A second, smaller burn pan, designed for use with mortar training units, was also demonstrated. The smaller size of the unit allows easier movement and is built to accept the smaller charges encountered during mortar unit training. The mortar training unit burn pan is designed for charge loads of less than 50 kg/burn.

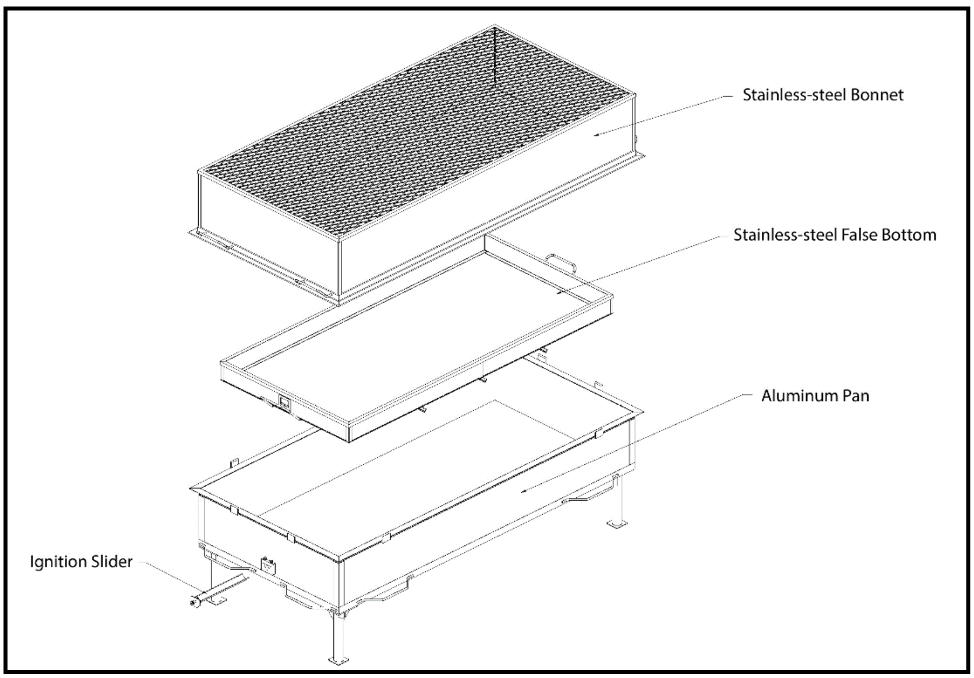


Figure 2. Assembly drawing of the Artillery/Howitzer Training Unit Burn Pan

The burn pan system was developed over a 10-year period. High energetics and heavy metal residues were found around a fixed burn pat on Ft. Greely (now Donnelly Training Area), AK, when the area around the pan was characterized under work sponsored by the US Army Alaska. [12]. That finding led to characterizing expedient field burning of propellants

following mortar unit training exercises in Alaska during SERDP Project ER-1481 research on firing point contamination from 2006 through 2008. In 2010, a portable burn pan was constructed and tested at the Defence Research and Development Canada's test range in Valcartier, QC [2] [13]. Based on these tests and ongoing development work by DRDC on a fixed-location propellant burn pan, modifications were made to the portable pan designed and a second prototype built and tested in Alaska in 2011 under ER-1481 [2]. ESTCP funded further development and demonstration of the portable burn pan concept in 2013, and three test and demonstrations were conducted through 2015. A final design was completed and a unit built for an outside customer the end of 2015 (Table 2).

Table 2. Chronology of the development, testing, and demonstration of the CRREL Portable Propellant Burn Pan training device.

Year	Activity	Outcome	Publications
2006	Test burn on snow of mortar propellant	Documented high residues mass following burn	[14]
2007	Characterization of a Canadian OB/OD range	Discovery of significant quantities of propellant grains from improper disposal	[15]
2008	Characterization of burn points Mortar propellant charge burn test on snow. Test burn of 105-mm propellant charge bags on clean sand. Canada starts fixed burn pan development	Very high concentrations. Propellant grains recovered from burn location next spring. Lower but still significant propellant residues remaining.	[2] [12] [16]
2009	Burn test on soil: Triple-base howitzer propellant (Canada) Canadian tests initial burn pan designs US Starts burn pan development	Finding of variability in propellant burn efficiencies. First Canadian burn pan designs and revisions.	[1] [17]
2010	Canadian fixed pan and US portable pan tests in Canada	Successful tests. Design improvements initiated in both countries.	[12] [13] [18]
2011	Continued revision and testing of burn pan designs	Continued improvements in design and performance	
2012	Canada finalizes design. DRDC writes up SOP for pan use.	Implementation of burn pan in Canadian	
2013	Redesign, test, and demon-stration of full-sized burn pan Work with ARNGB on burn pan BMP guidance	Highly successful test. Draft ARNG BMP on burning excess propellant training.	[19]
2014	Redesign, test, and demon-stration of smaller burn pan. Redesign of full-sized burn pan.	Highly successful test.	[20] [21]
2015	Redesign, test, and demon-stration of full-sized burn pan. Final pan revisions.	Highly successful test. Burn pan design completed.	[22]

The primary use for the portable propellant burn pan is to enable a safe, environmentally responsible means for conducting excess propellant burn training during artillery training. Because of the robust design of the device, other energetic materials may be addressed in the pan, such as small masses of explosive filler, pyrotechnic devices, or simulators, but these items have not been tested in the pan.

2.2 Technology development

The burn pan concept came about while characterizing military indirect firing points, fixed propellant burn pan locations, munitions disposal ranges, and open burn/open detonation (OB/OD) ranges. Large amounts of unburned propellant grains were found at many of these locations (**Fig. 3**). Subsequent tests showed that up to 20% of the propellant to be burned remained as residues following a burn event **[1]**. Fixed burn pans seemed to be especially problematic as they concentrated the unburned residues, were generally isolated from the firing points, required transport of highly combustible excess propellant over long distances, and often did not afford the training unit an opportunity to conduct propellant burn training as the burn was conducted by Range personnel.

In 2009, Defence Research and Development Canada–Valcartier (DRDC), Val-Bélair, QC, Canada and the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH, embarked on parallel tracks for the development of burn pans: In Canada, the emphasis was on a fixed design for central disposal of excess artillery propellant, similar to the existing central disposal concept in use in the US and Canada but with a much cleaner engineered system. In the US, we focused on a portable training device that will allow soldiers to continue to burn propellant at the firing point during and following live fire as part of their field training **[13]**.

Testing in Canada began in 2009, and much development work occurred to refine the design. In 2010, a joint test was conducted at DRDC with the fixed Canadian design and a semi-portable US design. Following these tests, the Canadians shared their technology with the US team, who modified their design to incorporate some aspects of the Canadian design. A second portable pan was designed, built, and successfully tested in Alaska with a training Army artillery unit (**Fig. 4**). This design was the basis for an ESTCP proposal that was funded in December 2013.

a) Propellant grains found at a munitions disposal range

b) Propellant grains found at a winter burn training site

Figure 3. Post-disposal propellant found on ranges

a) Set up at artillery firing point b) Test burn of 65 Kg M1 propellant

Figure 4. Prototype burn pan developed under SERDP ER-1481

2.3 Advantages and limitations of the technology

The primary benefit to the DoD will be a significant reduction in propellant residues on training ranges through the controlled expedient field disposal of excess propellant charges. Because the pan is a training device and not a fixed disposal facility, it has the added benefit of not coming under restrictive environmental regulations.

The advantage of the portable burn pan centers on two primary areas. The first is troop training. The use of the pan will allow units that are training with indirect-fire munitions to burn excess propellant charges at their firing points. This is very important because excess propellant disposal is part of combat operations and training on this activity is limited by several factors. Many ranges simply do not allow the burning of propellants on the ground because of the potential contamination risk and the previously uncontrolled nature of these burns. They also require the transportation of excess charges to remote burn facilities, which results in the absence of soldiers from the training site. When the burns at these central sites occur, only a limited number of soldiers are able to participate, if they are allowed to participate at all. By having a portable burn pan accessible at the training site, disposal of the excess charges is much more efficient, straightforward, and opens up a valuable training opportunity to more of the troops. We never had any problem enlisting volunteers to take part in

the tests and demonstrations conducted during joint exercises with training units.

The second major benefit is the reduced environmental impact of the training activity. Uncontrolled burns on the ground at firing points or unsupervised burns at fixed burn pan sites have resulted in significant contamination of the soils in these areas. Unburned propellant and heavy metal residues were found to be extremely high (>5,200 ppm) at one fixed burn pan site and unburned propellant approaching 20% of the original mass was found following a winter burn at an open burn site near a firing point **[12]**. With the use of the portable burn pan, residues are greatly reduced, in some instances to undetectable levels on the soil surrounding the pan.

The only disadvantage that comes to mind is the limited capacity of the portable burn pans and the size of the burn. Although 50, 90, or even 120 Kg of propellant per burn may sound like a lot, a field exercise may involve 18 guns or more. Over a thousand kilograms of excess propellant may result from an extended training exercise. I spoke to an artillery battalion commander about this and he said it would not be a particular problem if burns occurred at the end of each firing mission throughout the training. He also thought it would be an opportunity for more of his artillerymen to train on burning propellant.

3.0 Performance Objectives

The performance objectives are designed to obtain a quantitative assessment of both the effectiveness of the portable burn pan as well as factors that will affect its ease of use. A detailed description of each quantitative performance objective, its data requirements, and the success criteria follows. These are summarized in **Table 2**.

The objectives and results that follow concentrate primarily on the full size pan, which is the system that is described in the ESTCP Statement of Work and Demonstration Plans for Project ER-201323. Because of the exceptional performance of the first burn pan designed and tested for ER-201323, we designed and built a smaller burn pan system designed specifically for use with mortar training. This unit had as design objectives a 50 kg mass burn capacity, the same reduction of mass of charges (combustible mass) and energetics, a unit weight goal of 80 kg with component weights not to exceed 50 kg each, and less than 10% of lead outside the pan following a propellant burn. The qualitative objectives are the same as for the full-size (howitzer) burn pan system. The success criteria as well as the results for the mortar training system will be enumerated in the text following **Table 3**.

Table 3. Performance Objectives

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
Burn capacity	Pre-test weighing of charges	120 kg total mass of charges while meeting the following criteria	Able to burn up to 120 kg. Recommend 90 kg.
Reduction in mass of charges	Pre- and post-burn mass of test material	99.9% reduction in combustible mass	99.98% mass reduction
Reduction in mass of energetics	Analysis of samples obtained pre- and post-burn outside of burn pan for COC concentrations	Less than 0.01% of original energetics mass recovered outside of burn pan	No significant difference in soil COC concentrations following burns
Unit mass	Weighing of components	<130 kg total mass <70 kg/component	119.3 kg total mass <43.2 kg /component
Containment of heavy metals	Mass of lead outside burn pan	<10% of total mass	Unable to obtain data: No lead in charges
Quick turnaround	Temperature of residues	<100°C above ambient w/in 15 minutes of burn	Turnaround time of 12 minutes (load to load)
Qualitative Performance Objectives			
Integration of burn pan into training	Feedback from troop field commander	Acceptance of concept of burning in the pan	All feedback positive
Ease of use	Feedback from troops on usability of technology and time required	Ability of troops to safely and effectively utilize the technology	Self-reliant after one burn
Environmental and Range Control acceptance	Feedback from installation Environmental Office and Range Control	Understanding the benefits of the system and willingness to mandate its use	Achieved at all three installations. Requests for additional pans from all sites.

3.1 Burn capacity

Burn capacity is the mass of propellant charges that can be safely and effectively burned in a single event. Efficiency is based upon the reduction of the combustible mass, the mass of contaminants of concern (energetics and metals) recovered outside the structure, and the turnaround time between burns. These factors are listed as additional performance objectives below.

3.1.1 Data requirements

Mass of propellant charges in a burn.

3.1.2 Data collected

The mass of propellant per burn was obtained using a field scale (±0.1 g resolution). The mass loaded was adjusted to fit the environmental conditions when appropriate.

3.1.3 Data assessment

The data were straightforward and not subject to interpretation. We recommend that the maximum propellant load be used at all times as environmental and climatic conditions may require smaller loads per burns to avoid collateral effects such as grass fires. The criteria were successfully met for the full size (howitzer) system. One spot-weld on the bonnet failed during the demonstration of the burn pan. The observer from the Range office assessed the failure as minor and easily repairable.

The amount of propellant available for testing the smaller mortar system (16 kg) did not allow us to test at the design load of 50 kg. At 16 kg, the mortar system pan experienced no structural failure.

3.2 Reduction in the combustible mass of charges

Charge mass reduction is a measure of the decrease in mass of the combustible portion of the propellant charge. This mass includes the charge bag, energetics, and the combustible non-energetic components of the propellant charge. Not included are metals and such non-combustible charge components such as flash suppressants. The majority of this mass will be contained within the burn pan. The mass in the pan was measured to determine the mass reduction from the burn. The initial residues was collected, separated according to type (bag fragments, propellant grains, and ash) and re-burned to determine residual combustible mass from the various residues components.

3.2.1 Data requirements

Pre-burn mass of propellant charges, post-burn mass of ash (residues) in pan, mass of metals and non-combustibles in charges. Post-burn secondary burn of residues to determine combustible mass of the initial residues.

3.2.2 Data collected

Post-test and -demonstration material remaining in the pan was removed, dried, and massed using a laboratory scale (±0.01 g resolution). The mass was burned to obtain the fraction that was non-combustible. The non-combustible mass was then massed.

3.2.3 Data assessment

The data were straightforward and not subject to interpretation. The criteria were successfully met for all tests and systems.

3.3 Reduction in the mass of energetics

Energetics mass reduction is a measure of the decrease in mass of the energetic compounds in the propellant charges. This mass was measured outside the pan, as the most important component of the residues is what is deposited in the environment as a result of a disposal action. Energetics contained within the pan were subjected to subsequent burns and controlled disposal when the ash is collected during periodic maintenance of the unit. The mass of energetics ejected from the pan was collected using replicate multi-increment sampling from the ground or snow surrounding the pan or collected from trays placed around the pan to reduce measurement error **[23] [24] [25]**. We also measured the mass of the propellants and the mass of energetic compounds recovered from within the burn pan before and after the secondary burn.

3.3.1 Data requirements

Original mass of energetics in the charges. The post-burn mass of energetics in the soil or snow samples (Figure 2). The mass of propellant in the pan following the initial burn of the charges. The mass of the various energetic compounds remaining in the secondary burn residues.

3.3.2 Data collected

Soil or snow samples were taken before and after each burn or set of burns were complete. Pre-burn samples were taken to establish a baseline against which the post-burn results could be compared to determine the mass of each analyte on the ground. Analyses were conducted using high-performance liquid chromatography – ultraviolet detector (HPLC-UV) and

standard methods for nitroglycerin (NG) and di-nitrotoluenes (DNTs) [26].

3.3.3 Data assessment

Because of the very low mass of ejected energetics, we were not able to discern any difference in soil concentrations of the analytes of interest. For tests conducted previous to ER-201323 on snow, we could detect an increase in the concentration (and mass) of the analytes, but they were well below the target criteria (Fig. 5). The criteria were thus successfully met for all systems and all tests.

Figure 5. Yellow post-burn residues on snow adjacent to burn pan (65-kg burn test)

3.4 Unit mass

The mass of the burn pan unit is an important factor in the determination of the ease of use. The pan should be easily maneuvered by no more than four personnel. The bonnet should be easily handled by two personnel to reduce the number of personnel involved in the loading and lighting of the propellants in the burn pan.

3.4.1 Data requirements

Mass of complete unit and components.

3.4.2 Data collected

Each component was massed separately to obtain component masses and the whole system was assembled to determine the unit mass and to verify the component masses. A set of piezoelectric sensors with a resolution of ±0.1 g was used to obtain the data.

3.4.3 Data assessment

The data were straightforward and not subject to interpretation. The final mass of the howitzer system is 119.3 kg and of the mortar system is 79.3 kg. Component weights for the howitzer system do not exceed 44 kg and for the mortar system all components weigh less than 30 kg. All criteria were successfully met for both systems.

3.5 Containment of heavy metals

Heavy metals (lead) are used in some propellant charges to remove copper contained in the rotating bands of the projectiles from the rifling of the weapon barrel. This material is found in thin lead strips within one or more propellant charges. If these charges are excessed and burned, the lead can be ejected from the pan during the burn or aerosolized and carried outside the pan by the burn plume, to be deposited in the vicinity of the pan (**Fig. 6**). These fine lead particles then become an inhalation hazard in the dust kicked up around the pan or are relatively quickly transported into the groundwater. Only the lead ejected from the pan poses an immediate and long-term hazard, as the remainder is contained in the pan as either larger, non-transportable particles or bound in the ash residues. The mass of lead ejected from the pan will be collected using replicate multi-increment sampling from the ground or snow surrounding the pan or collected from trays placed around the pan. Completion of this task will require access to propellant charges containing lead, which is not common.

3.5.1 Data requirements

Original mass of lead in the charges and post-burn mass of lead in the samples.

3.5.2 Data collected

None of the tests with the three different pans used propellant charges containing lead foil, the greatest source of heavy metals. Lead is a component of the propellant grains for M1 propellant burned during the demonstration at Delta Junction, Alaska. We sampled pre- and post-burn soil samples with a Niton and a new Innov-X X-Ray Fluorescence instrument to determine if elevated lead levels could be found in the soil as a result of the burning of over 1000 kg of propellant. There was no significant difference (≈20 ppm in both locations). We also checked for lead in the ash residues of the pan. Lead levels were much higher (≈20 ppt) within the pan.

Figure 6. Lead from the decoppering foil in propellant charge following burn events. Lead foil remnants with a partially burned charge bag on soil near a fixed burn pan, lead foil with propellant grains on the ground adjacent to a fixed burn pan, and fine lead particles on the 3-mm steel open-mesh grate of a prototype portable burn pan following a 120-kg test burn.

3.5.3 Data assessment

These data are subject to interpretation. The low levels found outside the pan made discerning any significant difference impractical. There was much data overlap between the six pre- and post-demonstration samples. The elevated lead levels within the pan were an interesting find and may help explain the very high lead concentrations detected in soils around fixed burn pans. The data for the residues within the burn pan are qualitative as the medium sampled was ash rather than soil. Ash samples are to be analyzed on an Inductively-Coupled Plasma (ICP) instrument.

3.6 Quick turnaround

Quick turnaround, the ability to reload the pan with propellant charges after a burn, is essential for the efficient use of the burn pan. Intensive

training missions or missions with larger-caliber weapon systems may generate excess propellant is quantities exceeding the safe loading capacity of the pan. If this occurs, multiple burns will be required. Reloading of the pan can only take place when the pan has sufficiently cooled to allow placement of the charges without accidental ignition. To determine the temperature of the pan and residues, thermocouples were placed at strategic locations on the pan and an IR scanner used to determine the temperature of the residues. Elapsed time commenced at the determination of safe access to the burn pan.

3.6.1 Data requirements

Temperature of the relevant pan components and the ash. Elapsed time from initiation of loading the pan to safe re-initiation of the following loading of the pan. Safe clearance of the burn (burn-down of propellant complete and safe to add the next load of propellant).

3.6.2 Data collected

Thermocouple sensor data and IR camera data for temperatures, elapsed time data for the various components of the propellant burn training process.

3.6.3 Data assessment

Initial data (first two tests) was piecemeal as we tracked times for separate activities associated with a training exercise. For the demonstration, we had six burns and were able to derive contiguous burn times. For the artillery pan, the turnaround time was 12 minutes. For the mortar pan, the turnaround time was five minutes. Both units successfully met the criteria.

3.7 Integration of burn pan into training

Training unit commanders were queried before and after test burns to determine if they felt that the burn pan could be integrated into their training regimen. All three commanders not only appreciated the opportunity to have a burn pan on site with which they could train their soldiers on burning of excess propellants, they all requested a burn pan for their units. This does not imply that all commanders will embrace the burn pan. One artillery unit commander at a test prior to the ESTCP project was very up-

set with the presence of the burn pan at his training site and refused to allow his soldiers to participate in the test. However, his replacement was the commander of the training unit that assisted us during the demonstration. He was enthusiastic about the pan as was his command sergeant major and the deputy commander. He requested that we leave the pan at the site so his troops could continue training on it until their exercise ended. All the commanders provided valuable feedback at the end of the exercise. One requested that we build a burn pan for his unit so he could use it on all training exercises.

3.8 Ease of use

Operation of the pan is quite straightforward. None of the artillerymen who assisted us with the tests and demonstration had any problems grasping the concepts or operation of the burn pan. We never lacked for volunteers to assist us, not only with the pan but also with the baseline soil sampling. The troops were very attentive and helped in whatever way they could. They also provided very valuable feedback on the pan and its operation, an indication of their interest and enthusiasm for the burn pan system. It helped that they got to torch up to 120 kg of propellant, which was quite an experience for them.

3.9 Environmental and range control acceptance

The Environmental Officers of the facilities at which we conducted the tests requested the initial two tests. The demonstration was conducted at the request of the Range Officer. In all three activities, both Range and Environmental were enthusiastic supporters and embraced the concept of a portable burn pan for unit training. At Camp Grayling, MI, the Range Officer cancelled a contract for a centralized fixed burn pan facility, preferring to integrate the portable burn pan into the facilities standard operating procedure. All facilities requested the test pans remain at their facilities as well as additional burn pans. Donnelly Training Area Range ordered two with an option of an additional unit.

4.0 Site Description

Three sites were chosen to conduct tests and the demonstration. The first location was Camp Grayling, MI, an Army National Guard base in the northern part of Lower Michigan. The second was Fort Indiantown Gap, PA, located in southeastern Pennsylvania. The third was Donnelly Training Area, AK, located on the former Fort Greely near Delta Junction in central Alaska.

4.1 Site location and history

4.1.1 Camp Grayling, Michigan:

The location of the first test of a prototype burn pan under ER-201323 was Camp Grayling, MI. Camp Grayling is the largest Army National Guard (ARNG) training facilities. This facility allows ARNG troops to train with both mortars and howitzers. Arrangements were made with Mr. John Hunt, Environmental Manager at Camp Grayling (CGMI), to conduct a test on his post. The 1/134th Ohio ARNG volunteered to participate in the tests. Coordination was through 1SG Scott Zaebst and CPT Patrick Rippeth. Planning and coordination went smoothly.

4.1.2 Fort Indiantown Gap, Pennsylvania

The location of the second test of a prototype burn pan under ER-201323 was Fort Indiantown Gap, PA. Ft. Indiantown Gap (FIG) is a large ARNG training facilities that has ranges for ARNG troops to train with both mortars and howitzers. Arrangements were made with Ms. Jo Anderson, Environmental Project Manager at FIG, to conduct a test on her post. The 1/110th PA ARNG volunteered to participate in the tests. Coordination was through MSG Rom Maraffi and CPT Lawrence Fagan of the 110th and LTC Jim Fluck, Range Commander at FIG. Planning went smoothly although coordination with the training unit during the burn was somewhat erratic.

4.1.3 Donnelly Training Area, Alaska

The location of the demonstration of the final design of the burn pan under ER-201323 was the Donnelly Training Area (DTA) on the former Fort Greely, AK. At around 275,000 ha, DTA is one of the largest Army training facilities in the US with many indirect-fire ranges. Arrangements were

made for conducting the burn pan test at DTA with Mr. Steve Thurmond, the USARAK Range Manger for DTA. Mr. Joe Clark of Range Control assisted us in the field. The 2/377th PFAR, Joint Base Elmendorf-Richardson (JBER), agreed to train on the burn pan with excess propellant from their concurrent training exercise. Coordination with the training unit was through SSG Emmanuel Rodelo and CPT Liuzzu. Planning and coordination went smoothly.

4.2 Site geology/hydrogeology

4.2.1 CGMI

Firing Point 301 on the north side of CGMI was the location at which the artillery unit was training generating the excess propellant was training. The firing point is a sandy, sparsely vegetated open area with low discontinuous grass (**Fig. 7**). Recent rains had moistened the soil, making it cohesive. Geology of the site had no effect on the test design or the test. No standing water was present at the site, even after a hard rain. The presence of standing water was the only hydrological concern for the test design and the tests.

4.2.2 FIG

Firing Point 1-10 on the north side of FIG was the location chose for the test burn. The firing point is an open area composed of packed coarse gravel with sparse vegetation consisting of mostly low discontinuous grass (**Fig. 8**). There was no rain forecast and no standing water in the area of the test.

4.2.3 DTA

Firing Point Sally on the north side of CGMI was the location at which the artillery unit was training generating the excess propellant was training. The firing point is an open vegetated area with a ground cover of grasses, sedges, low forbs, and some low shrubs. Soils are fine-grained silt loam overlying coarser, poorly sorted gravel (**Fig. 9**). Topography is relatively flat with some rolling areas. Geology of the site had no effect on the test design or the test. No standing water was present at the site, even after a hard rain.

Figure 7. Firing Point 301, CGMI, with burn pan on site

Figure 8. Firing Point F-1-10, FIG, before placement of burn pan (rt.)

Figure 9. Firing Point Sally, DTA, with burn pan on site

4.3 Contaminant distribution

For all test locations, a location was chosen for the burn pan at least 100 m downwind of the artillery firing positions. At FIG and DTA, the burn points were located on adjacent ranges. Baseline soil samples were taken to characterize the site for propellant residues prior to the test burns. An area 6 m in diameter was sampled in triplicate with the CRREL multi-increment (MI) sampling tool using a 3-cm coring bit set at 2-cm depth **[23]**. Sampling methods are discussed in Section 5.5. An additional area from 3 to 6 m from the pan location center point (6 – 12 m diameter) was also sampled in the same manner. These areas were resampled in triplicate following the burn to determine propellant residues surface deposition. The diameters chosen for sampling were based on previous experience utilizing prototype burn pans. Baseline data for the three sites can be found in **Table 4**. Data for the fixed burn pan at OP-7 on DTA is given as a reference.

Table 4. Baseline energetics residue data for burn points

Site	DNT (mg/kg)	NG (mg/kg)	Lead (mg/kg)	Reference
CGMI				[19]
0 – 3 m	1.8	—[3]	—[2]	
3 – 6 m	0.95	—[3]	—[2]	
FIG				[20]
0 – 3 m	0.95	2.0	—[2]	
3 – 6 m	0.84	2.2	—[2]	
DTA				[22]
0 – 3 m	4.8	—[3]	21.	
3 – 6 m	4.5	—[3]	16.	
CGMI Fixed Pan	48.	—[1]	5100.	[3] [4]
OP-7 Fixed Pan	35.	6.4	5100.	[1] [2] [27]

[1] Not reported

[2] Not an analyte of interest for these tests (no lead foil in charges)

[3] Below analytical instrumentation detection limits

5.0 Test Design

Testing of the portable burn pan took place on three active military installations on which indirect-fire training is taking place. Tests were conducted through the installation Environmental Resources Manager or the Range Manager and in association with troops training in the field. The troops were tasked by the officer in charge (OIC) to conduct the actual prototype test and demonstration burns under the guidance of the project PI. Excess propellant bags generated during the troop training exercise were used for the burns.

5.1 Conceptual experimental design

The basic performance of burn pan was measured based on the percentage of analyte mass recovered from outside the pan following the propellant charge burn. Troops from an artillery training unit conducted all tasks associated with training with the burn pan while technical staff from CRREL weighed and characterized the propellant charges, obtained and analyzed the pre-and post burn soil samples, collected and analyzed the post-burn residues within the pan, and measured the mass and operational use of the system.

5.2 Baseline characterization

The basic performance of burn pan was measured based on the percentage of analyte mass recovered from outside the pan following the propellant charge burn. Troops from an artillery training unit conducted the burns as part of their expedient field burning of propellant training while technical staff from CRREL weighed and characterized the propellant charges, obtained and analyzed the pre-and post burn soil samples, collected and analyzed the post-burn residues within the pan, and measured the mass and operational use of the system.

5.2.1 Soil sampling method

Soil sampling was conducted using the Mult-Increment® sampling method. The baseline samples were taken from a 0- to 3-m and 3- to 6-m annulus surrounding the burn pan (See Section 4.3). Samples in these two zones (sampling units: SUs) were collected in triplicate. Sample increments were 2-cm in diameter by 2.5-cm deep, taken with the CRREL Multi-Increment Sampling Tool **[23].** A minimum of 40 increments were

taken from each SU to construct a sample. Samples were analyzed using EPA Method 8330b, developed at CRREL [26].

5.3 Treatability or laboratory study results

Initial research on the topic of contamination from the burning of excess gun propellant was conducted as part of SERDP project ER-1481 [1] [16]. These studies included sampling of a fixed burn pan in longtime use [27] and evaluating the performance of two portable burn pans constructed to determine the ability of a purpose-designed piece of training equipment to contain energetics and metals [2] [13]. These studies indicated that current practices of burning of excess propellant on the ground, especially when the ground is covered with snow, will result in significant (%-level) deposition of energetics [16]; that the current burn pan design used in the US is inadequate for the efficient disposal of propellants [3] [27]; and that a properly designed portable burn pan will significantly improve both the burn efficiency and containment of energetics [2] [13]. Canadian researchers at DRDC, following a parallel track to US research at CRREL, were the first to substantially prove that a purpose-built propellant burn pan is capable of both clean, efficient disposal of excess propellants as well as the containment of heavy metal and energetic residues [13]. These studies were the basis for ESTCP Project ER-201323.

5.4 Design and layout of technology components

The CRREL portable propellant burn pan is a training device designed specifically to enable soldiers to conduct safe, environmentally responsible burns of excess howitzer and mortar propellants while gaining valuable training on the handling and disposal of propellant charges in the field. The major component of the tests was the portable burn pan, previously described in **Section 2.1**. Instrumentation for the first two tests included a datalogger and associated sensors (thermocouples) to measure and record burn pan component temperatures as well as the ambient air temperature. For the demonstration, an camera was used to monitor the pan temperature. For all tests, a field scale was used to determine the mass of the charges that were loaded into the pan for each test burn.

5.4.1 Temperature sensors

Temperature sensors used for the tests were Type K (chromel/alumel) with a temperature range of -200°C to 1350°C. Sensitivity of Type K thermocouples is 41 μV/°C. Two sensors were placed on the underside of the false bottom along the centerline a third of the distance from either end. Two sensors were bolted on the long side of the aluminum base, half way up the side and 1/3 the distance from either end. Two more thermocouples were tied with metal wire to the long side of the perforated stainless bonnet, half way up the side and 1/3 the distance from either end. A sensor was also positioned 30 cm above the middle of the top of the bonnet to measyre the burn temperature. The sensors were tied into a Campbell AMT-25 multiplexer. A Campbell CR-10X datalogger was used to record the sensor output. The datalogger and multiplexer were located 5 m from the burn pan within a protective enclosure that in turn was protected from the radiant heat of the burn by reflective aluminum foil. An ambient sensor was located within the CR-10X enclosure.

5.4.2 Infrared camera

To make the training experience more realistic for the artillerymen, we used a remote temperature sensing system (infrared video camera) to record and monitor the temperature of the burn pan. The camera was a FLIR® S60 IR Camera with the sensing range set to -10°C to +580°C (±2°C accuracy / -40 to 1500°C range) **[28]**. The storage capacity of the camera was limited to 155 sec, which gave us sufficient time to monitor the temperature of the burn as it passed the 100°C mark. However, the storage ran out before the pan reached 40°C, the temperature at which all components of the pan could be comfortably handled without gloves.

5.4.3 Field scale

The scale used in the field to weigh the propellant charges to be burned was an Acculab SV-50. The SV-50 has a capacity of 50 kg. The scale has a resolution of 0.01 kg. Calibration of the scale took place within a year of field use, and the scale was evaluated prior to and after field use with standard weights of known mass.

5.5 Field testing

The burn pan technology had been tested on two occasions prior to the start of ER-201323. The objectives of this project required the completion

of the development of the pan. Each iteration of the design needed to be tested in the field to determine if the performance objectives (**Table 3**) were being met. An important part of the field-testing was obtaining feedback from the users, which was used to optimize the design of the pan.

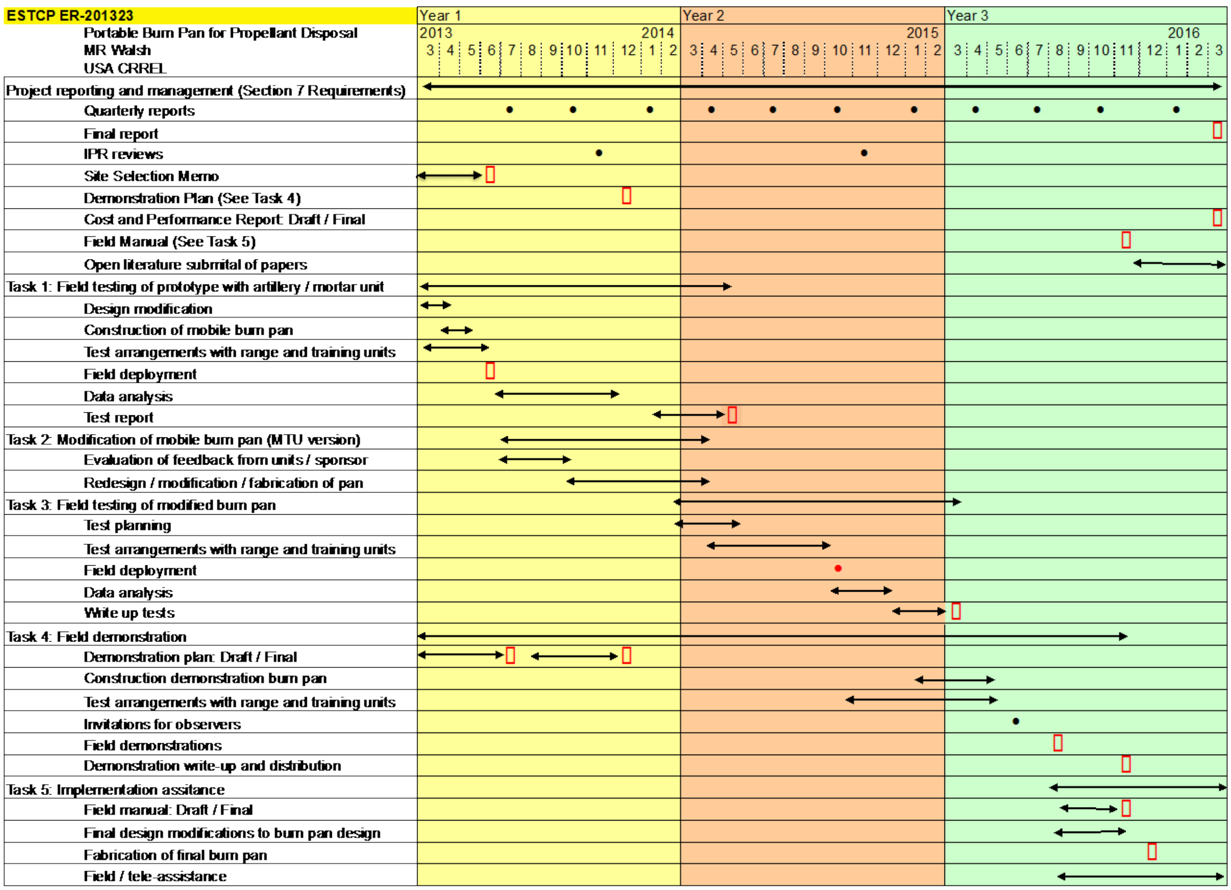
Three portable burn pans were designed, built, and tested as part of the project. The first pan was a full-size pan, an iteration of the previous two pans, designed to be a general purpose pan capable of handling propellant burns from all types of training up to howitzer battalion operations (HTU burn pan). The interior dimensions of the false bottom of this pan, the area where the charges are loaded for burning, measures 0.9 m x 1.9 m. The success of the first test allowed us to design, build, and test a smaller mortar training unit (MTU) burn pan, which incorporated the design improvements of the previous pan in a smaller, more easily handled unit. This burn pan measured 0.9 m x 1.0 m inside the false bottom. The third prototype was built using lessons learned from the previous two tests. This prototype was demonstrated to assess the performance of the pan with respect to the objectives outlined in **Section 3** to determine the maturity of the technology. Only minor changes based on performance and user feedback were made to the final design, which was completed at CRREL.

A model of the final design has been fabricated by CRREL for the US Army Alaska at their request. The design was simplified for manufacturing and the mass reduced 10 kg. A protocol was developed along with the testing of the prototypes for a final users' manual (sent to ESTCP). This protocol encompasses all the operations necessary to conduct a field burn of excess propellant charges using the portable burn pan. The burn pans used during the test and demonstration phases of the project were turned over to the Environmental or Range Mangers at the facilities on which they were tested. All three facilities requested additional pans. Unfortunately, I did not obtain requests from the responsible entities at the facilities to retain the burn pans. However, the enthusiasm by the facility partners for the pans was quite a pleasant surprise. All three points of contact have left their positions since the tests.

No decommissioning or site remediation was required following the tests. All waste material (ash) was removed from the pans and returned to CRREL for analysis to determine if the performance objectives for combustible mass and energetic compound reduction were met.

The following Gantt chart (**Table 5**) depicts the flow of tests through the demonstration and final documentation. The testing process was designed to allow for building of improvements into the design of the pan over time. Significant improvements were made over the course of the two tests previously conducted. The design was refined and made more user-friendly in the follow-up designs.

Table 5. Gantt chart for execution of ESTCP Project ER-201323



5.6 Sampling methods

Sampling took place in two general areas: Inside the pan and outside the pan. The objective of taking samples outside the pan was to determine the increase in mass of analytes (NQ, DNT, Pb) on the ground resulting from a propellant burn. Those taken from inside the pan were used to determine mass reduction, unburned combustibles mass, and energetics constituent mass in the final ash.

Table 6 presents an overview of the sampling plan for the prototype testing and the final demonstration of the technology. Sampling was the same

for all three of the tests with the exception of the lead work, which was done only for the demonstration in Alaska. The analytical methods used are presented in **Table 7**. All samples were processed and prepared for analysis at the analytical laboratory at CRREL. Energetics and handheld-characterization for lead (Niton and Innova XRF instruments) analyses were conducted at CRREL **[29]**. The lead analyses of the ash collected following the DTA tests will be conducted at ERDC's Environmental Laboratory.

Samples from outside the pan (external) were collected from two annuli surrounding the burn pan: 0 - 3 m and 3 - 6 m. We collected all the soil sample using the multi-increment sampling technique . The samples were composed of at least 40 increments. The increment size was 2-cm ø by 2-cm deep. Samples were ground and subsampled in accordance with EPA Method 8330B to ensure the samples were representativeness of the samples and reproducibility of the data **[26] [30] [31] [32]**.

Table 6. Total Number and Types of Samples Collected for Project Demonstration

Component	Matrix	Number of Samples	Analyte	Location
Pre-burn (baseline) sampling	Soil	3 Replicates[1] 44 Increments Ea. (Mean)	2,4-DNT 2,6-DNT NG	0 – 3 m from pan
		3 Replicates[1] 66 Increments Ea. (Mean)		3 – 6 m from pan
		6[2]	Lead	Using material from energetics samples
Technology performance sampling	Burn residue (Ash)	2[3]	2,4-DNT 2,6-DNT NG	One from pan One from false bottom
		7	Lead	False bottom
Post-demonstration sampling	Soil	3 Replicates[1] 55 Increments Ea. (Mean)	2,4-DNT 2,6-DNT NG	0 – 3 m from pan
		3 Replicates[1] 61 Increments Ea. (Mean)		3 – 6 m from pan
		6[2]	Lead	Using material from energetics samples

[1] Multi-increment samples. Each increment approximately 3-cm ø by 2-cm deep.

[2] X-ray Flouresence scan of each processed replicate soil sample

[3] Whole-population (bulk) samples from the stainless steel false bottom and the bottom of the aluminum pan

Table 7. Analytical methods for sample analysis

Matrix	Analyte	Method	Container	Preservative[4]	Holding Time
Soil or ash (burn resdues)	2,4-DNT	8330B[1]	Pre-cleaned Polyethylene bag[1]	None. Keep cool until air dried and processed	>28 days[5]
	NG	8330B			
	2,6-DNT	8330B			
Soil	Pb	Niton-XRF[2]			Stable
Ash	Pb	Innov-XRF			
		6020A			

[1] Ref [26]

[2] Ref [29]

[3] Lab-grade bags

[4] Preservatives are not required for these samples. Energetics samples will be kept refrigerated.

[5] If air-dried and cool

5.7 Sampling results

Results will be presented for the three tests in the sequence in which the tests were conducted. Data for both the soil samples (outside the pan) and the ash within the pan will be presented. Other results for the tests that pertain to the performance objectives will be given in Section 6.0.

5.7.1 Camp Grayling, MI: 10 June 2013

The table below (**Table 8**) contains the results for the pre- and post-test soil sample analyses. The test material was M1 artillery propellant, a single-base propellant containing 10±2% DNT. A total of 91 kg of Charge 6 and Charge 7 were burned in the single test. The original mass of DNT in the charges burned was approximately 9 kg. There was no lead foil in the burn, so the samples were not analyzed for Pb. Low concentrations (0.78 mg/kg) of NG were also found in the pre- and post-burn samples, but M1 propellant contains not NG. Its presence is likely from small arms training on the same range.

Table 8. Analytical results for pre- and post-burn soil samples (mg/kg): CGMI

Samples	Analyte	Rep	Increments (0 – 3 m)	Sample Mass (g)	0 – 3 m (mg/kg)	Increments (3 – 6 m)	Sample Mass (g)	3 – 6 m (mg/kg)
Pre-burn (Baseline)	DNT	1	35	870	0.26	52	1400	0.62
		2	35	840	1.2	52	1400	1.3
		3	35	850	3.9	52	1500	0.92
		Mean	35	850	1.8	52	1400	0.95
Post-burn (Baseline)	DNT	1	38	1000	2.7	58	1400	0.19
		2	38	970	0.38	58	1400	0.15
		3	38	980	1.7	58	1400	1.7
		Mean	38	990	1.6	58	1400	0.68

Results from a Wilcoxon-Mann-Whitney Rank Sum Test analysis of the data sets indicates that there is no statistical difference between the pre-burn and post-burn soil sample results for the analyte DNT. The P value for the 1- to 3-m annulus is 1.0 and for the 3- to 6-m annulus the P value is 0.7, both well above the 0.05 thresh-hold for statistical difference. There is also no statistical difference between the pre- and post-burn data sets for the two sampled annuli.

The residues from the burn pan were analyzed for DNT content. Both 2,4- and 2,6-DNT were analyzed (**Table 9**). The final mass of DNT in the residues was 1.5 g, or <0.02% of the original 8 kg mass of DNT for the burn. There is no performance goal for DNT in the pan residues. The final bulk volume of the residues was <1 liter. DNT makes up about 0.6% of the total remaining mass of the burned charges, well below the 10% waste stream contaminant level trigger point for RCRA hazardous waste designation.

Table 9. Analytical results for post-burn pan residues sample: CGMI

Samples	Residue Mass (g)	2,4-DNT Mass (g)	2,6-DNT Mass (g)	DNT Percent of Residue Mass[3]
Ash	180	1.4	0.057	0.83%
Propellant[1]	75	0.021	0.0012	0.03%
Bag[2]	15	0.0046	0.0004	0.03%
Total	270	1.4	0.059	0.55%

[1] Unburned grains of M1 propellant

[2] Combustible remnants of charge bags (It was raining during burn)

[3] Mass of DNT as a percent of sampled material

5.7.2 Fort Indiantown Gap, PA: 19 October, 2014

The test material was a mix of mortar propellant charges, mostly containing M38 propellant, a single-base propellant that, in its reworked form,

can contain up to 2% NG and 1% DNT. A total of 16 kg of propellant charges were burned in the single test.

The table below (**Table 10**) contains the results for the pre- and post-test soil sample analyses. The data show that there was no significant increase in NG concentration in the soil surrounding the burn pan in either the 0-3 m annulus or the 3-6 m annulus surrounding the pan following the 16-kg test burn. There is also no significant difference in concentrations before and after the test burn for the compound DNT. There is overlap in the pre-and post-burn data for DNT, with an elevated concentration for one post-burn sample rep for the 3-6 m annulus. This is likely a particle artifact from a previous burn activity at the site, a phenomenon also seen in prior characterizations of burn points. We have found that a single propellant grain can significantly increase the concentration of target analyte in a sample.

The specifications for the M38 propellant do not include NG or any DNTs for manufactured product **[33]**. However, reworked propellant may contain up to 2% by mass NG and up to 1% by mass DNT. The presence of NG in the post-burn ash recovered from the pan indicates that reworked propellant was included in the charge bags burned.

The residues from the burn pan were brought to the analytical lab for analysis (**Table 11**). The total mass of NG and DNT in the original combined charges is not known, as we did not return any unburned propellant grains for analysis. The lack of detectable DNT in the residues indicates that no DNT was in the reworked propellant. This was confirmed with a more sensitive analytical instrument, an HP Agilent 7890A gas chromatograph with an electron capture detector. Using the 2% value as a maximum, there may have been up to 320 g of NG in the propellant charges. If this were the case, then the burn efficiency for NG it would have been around 99.998%. The actual efficiency was likely lower, but we have no way to determine it. Because of the small mass of residues, we did not break out the initial components as we did with the CGMI samples (**Table 9**).

Table 10. Analytical results for pre- and post-burn soil samples (mg/kg): FIG

Samples	Analyte	Rep	Increments (0 – 3 m)	Sample Mass (g)	0 – 3 m (mg/kg)	Increments (3 – 6 m)	Sample Mass (g)	3 – 6 m (mg/kg)
Pre-burn (Baseline)	DNT	1	40	830	0.65	49	840	0.76
		2	40	900	1.2	44	950	0.85
		3	40	890	1.0	41	910	0.91
		Mean	40	870	0.95	45	900	0.84
	NG	1	40	830	1.9	49	840	10.
		2	40	900	1.6	44	950	0.78
		3	40	890	2.4	41	910	1.3
		Mean	40	870	2.0	45	900	4.0
Post-burn (Baseline)	DNT	1	41	840	0.95	49	1000	10.
		2	40	950	0.85	44	950	0.78
		3	41	910	0.56	52	1200	1.3
		Mean	41	900	0.79	48	1100	4.0
	NG	1	41	840	3.3	49	1000	2.6
		2	40	950	3.2	44	950	2.6
		3	41	910	2.1	52	1200	2.2
		Mean	41	900	2.9	48	1100	2.5

Table 11. Analytical results for post-burn pan residues sample: FIG

Samples	Residue Mass (g)	DNT Mass (g)	NG Mass (g)	NG Percent of Residue Mass[2]
False Bottom	30	BDL[1]	0.0035	0.011%
Pan (Base)	3.5	BDL	0.00078	0.022%
Total	34	—	0.0043	0.012%

[1] Analytical results were below detection limits for both 2,4- and 2,6-DNT

[2] Mass of NG as a percent of sampled material

5.7.3 Donnelly Training Area, AK: 14 August 2015

The test material was M1 artillery propellant, a single-base propellant containing 10±2% DNT. A total of 458 kg of Charge 6 and Charge 7 were burned in a series of six tests. The original mass of DNT in the charges burned was approximately 41 kg. There was no lead foil in the burn, but lead carbonate ($PbCO_3$) makes up 1% of the M1 formulation. Lead makes up about 89% of the $PbCO_3$, so there was a total of about 4 kg of Pb in the burns. We analyzed both the soil and the pan residues for Pb..

Soil samples were analyzed for both 2,4- and 2,6-DNT. **Table 12** summarizes the results. The data show that DNT contamination existed at the burn pan location prior to the test. The concentrations are of the same magnitude as we have found previously at this firing point and at other

burn pan test locations. There is no significant difference in concentrations before and after the test burn for the DNT compounds, with overlap in the pre-and post-burn data. It is likely that the burning of the grass and the extreme radiant heat from the multiple burns reduced the mass of any DNT that may have been expelled from the pan as well as any that resided on the soil prior to the tests. These results are consistent with data from the previous two tests with burn pans on the soil.

Table 12. Analytical results for pre- and post-burn soil samples (mg/kg): DTA

Samples	Analyte	Rep	Increments (0 – 3 m)	Sample Mass (g)	0 – 3 m (mg/kg)	Increments (3 – 6 m)	Sample Mass (g)	3 – 6 m (mg/kg)
Pre-burn (Baseline)	DNT	1	42	690	3.0	76	1400	4.7
		2	44	700	5.5	40	770	3.1
		3	46	760	5.8	81	1700	6.0
		Mean	44	720	4.8	66	1300	4.6
Post-burn (Baseline)	DNT	1	52	790	4.6	81	1700	5.9
		2	59	870	5.8	50	1000	3.1
		3	54	870	3.9	51	990	3.0
		Mean	55	840	4.7	61	1200	4.0

The residues from the burn pan were brought to the analytical lab for analysis. The amount of DNTs found in the ash is depicted in **Table 13**. The data are presented in three ways: as a total recovered mass, as a percent of the ash remaining in the pan, and as a percent of the estimated mass of DNT in the charges prior to burning. The percent of residue mass is important as it has implications for transport and disposal. The 0.33% concentration of DNT in the ash is quite low, allowing transport on public roads (<10% of total transported mass). The percentage of the original mass of DNT remaining in the pan is also quite low, much lower than found after previous burn tests. There is no ESTCP performance goal for DNT in the pan.

Table 13. Analytical results for post-burn pan residues sample: DTA

Samples	Residue Mass (g)	2,4-DNT Mass (g)	2,6-DNT Mass (g)	DNT Percent of Residues Mass[2]	DNT Percent of Pre-burn Mass[3]
False Bottom	41	0.054	BDL[1]	0.13%	0.0001%
Pan (Base)	58	0.28	0.0023	0.48%	0.0007%
Total	99	0.33	0.0023	0.33%	0.0008%

[1] Analytical results were below detection limits for both 2,4- and 2,6-DNT

[2] Mass of NG as a percent of sampled material

[3] DNT remaining from original mass of DNT in charges

The samples of the soil surrounding the burn pan did not indicate a consistent increase in the concentration of lead following the burn. Subsamples of all the ground soils were shot with an X-Ray Florescence (XRF) instrument (Niton 700 series) for lead content. Exposure time for each sample was determined by the stabilization of the standard deviation displayed on the instrument. Minimum recommended analysis time is 60 nominal seconds. The detection limit for the Niton 700 is ≈20 ppm for lead. Results are shown in **Table 14**. Pre-burn propellant grains were removed from a Charge 7 propellant bag and shot with the Niton XRF. Readings were below the 20 ppm lead detection limit of the instrument. Only one sample indicated a slight elevation in soil lead concentration.

The instrument produced accurate readings for the EPA RCRA standard sample supplied with the Niton instrument. Readings for 11 of the 12 samples were quite consistent, indicating that there was no significant increase in soil lead levels between the pre-burn and post-burn samples. One post-burn sample, 15FPSally-12, had a higher Pb level than the other samples, but even with that sample included with the other post-burn samples, the results do not differ significantly from the pre-burn lead levels (mean of 30 ppm vs. 20 ppm). This area is used as a small arms battle course (lead bullets) and was a firing position for the artillery unit just prior to our tests. The Charge 5 propellant bag, which contains lead foil, was used for all rounds fired from this position. Either of these activities may be the source of the single elevated detection of lead. All samples were well below the EPA recommended exposure level of <400 ppm.

The ash was examined with both the Niton instrument and a newer Innov-X XRF instrument. Results are presented in **Table 15**. The Niton results averaged 14,000 ppm (n=2) and the Innov-X results averaged 22,000 ppm. Both instruments were set up for soil, so the ash measurements are qualitative, indicating a high concentration of lead, but not able to return a true concentration. Samples have been sent out of the lab for further analysis on metals analysis instrumentation.

Table 14. Pb analytical results for soil samples: DTA

Sample	Reading #	Analysis Time (s)	Pb Conc. (ppm)
RCRA Standard[1]	144	103	480±19
RCRA Standard	147	104	490±19
Pre-test samples			
15FPSally-01	148	88	23±6.4
15FPSally-02	149	151	15±4.7
15FPSally-03	150	88	24±6.6
15FPSally-04	151	97	14±5.9
15FPSally-05	152	98	17±5.8
15FPSally-06	154	83	17±6.5
Means		100	18
Post-test samples			
15FPSally-07a[2]	148	85	20±6.2
15FPSally-07b	149	88	30±5.9
15FPSally-07c	150	103	28±6.1
15FPSally-08	151	90	15±6.1
15FPSally-09	152	93	23±6.3
15FPSally-10	154	121	18±5.2
15FPSally-11	154	82	19±6.5
15FPSally-12-1[3]	154	105	100±7.8
15FPSally-12-2	154	95	98±8.1
Means[4]		96	20

[1] USEPA Resource Conservation and Recovery Act standard sample (Concentration ≈500 ppm)

[2] Three separate subsamples of 15FPSally-07

[3] Duplicates of the same subsample of 15FPSally-12

[4] Means of samples 15FPSally-07 through -11

Table 15. Pb analytical results for post-burn pan residues sample: DTA

Sample	Reading #	Analysis Time (s)	Pb Conc. (ppm)
Niton 700 Series			
15FPSally–Ash-1[1]	165	103	14,000±95
15FPSally–Ash-2	166	152	15,000±79
Means		128	14,500
Innov-X XRF			
15FPSally-Ash-a[2]	2	120	17,000±130
15FPSally-Ash-b	3	120	23,000±180
15FPSally-Ash-c	4	120	23,000±180
15FPSally-Ash-d	5	120	23,000±180
Means		120	22,000
15FPSally-Ash-Bulk	6	120	17,000±140

[1] Duplicates of the same subsample of 15FPSally–Ash
[2] Four separate subsamples of 15FPSally–Ash

6.0 Performance Assessment

The CRREL portable excess propellant burn pan met or exceeded all performance objectives described in the Scope of Work for the project. The only objective that was not fully tested was the retention of lead in the pan from the M1 howitzer propellant Charge 5 lead foil. In all our tests, the Charge 5 module was used by the gunners. Performance objectives assessments will be addressed in the order they appeared in **Section 3, Table 3**. The performance objectives were developed for the full-size "artillery training unit" (ATU) pan. The objectives for the smaller "mortar training unit" (MTU) pan were derived from the ATU objectives, reduced because of the faster burn rate of mortar propellants.

6.1 Burn capacity

The performance objective for the burn capacity is 120 kg per burn for the ATU full-sized pan. For the smaller MTU pan, the objective was 50 kg. Results and an assessment appear in **Table 16**.

Table 16. Tested burn capacities for various models of the burn pan

Burn Pan	Test Location[1]	Maximum Test Load	Number of Tests	Assessment
ATU	DRDC	120 kg[2]	4	ER-1481: Much warping of top of bonnet
ATU	FRA	63 kg	1	ER-1481: System stable
ATU	CGMI	120 kg[3]	2	Some warpage of sides of false bottom
MTU	FIG	16 kg	1	System stable
ATU	DTA	89 kg[4]	6	One spot weld broke. Easy repair.

[1] DRDC: Defence Research and Development Canada – Valcartier, QC, Canada; FRA: Fort Richardson, AK; CGMI: Camp Grayling, MI, FIG: Fort Indiantown Gap, PA; DTA: Donnely Training Area, AK

[2] Average load of 97 kg

[3] Average load of 110 kg

[4] Average load of 77 kg

Our experience with the series of burns at DTA indicates that the burn capacity should be limited to 100 kg. The radiant heat from the 90 kg burns was enough to ignite nearby vegetation (**Fig. 10**). The unit should probably not be loaded more. The design was modified to reduce the capacity of the pans by reducing the heights of the sides of the false bottoms, thus guiding the artillerymen to place fewer charges in the pan.

Overall Assessment: The ATU burn pan is capable of meeting the performance objective of 120 kg per burn. However, for fire control reasons,

we recommend a 90 to 100 kg capacity limitation. There was not enough mortar propellant to test the capacity of the MTU, although it performed well at the tested capacity (16 kg).

Figure 10. Scorching of vegetation in vacinity of burn pan caused by radiant heat

6.2 Reduction in mass of charges

The performance objective for the reduction in the mass of the charges is 99.9% reduction of the total combustible mass. For the smaller MTU pan, the objective was the same. Results and an assessment appear in **Table 17**.

Table 17. Reduction in combustible charge mass for various models of the burn pan

Burn Pan	Test Location[1]	Number of Tests	Reduction in Mass	Assessment
ATU	DRDC	4	99.99%	ER-1481: Exceeded objective
ATU	FRA	1	—	ER-1481: Did not get mass of residues
ATU	CGMI	2	99.92%	Exceeded objective. Heavy rain during testing
MTU	FIG	1	99.98%	Exceeded objective
ATU	DTA	6	99.98%	Exceeded objective

[1] See Table 16

Optimal mass reduction was highly dependent on the dryness of the excess propellant charges. Wet charges proved difficult to ignite and did not burn well, resulting in some unburned propellant grains. If additional burns are planned and future charges are dry, the unburned combustible material should burn.

Overall Assessment: Both burn pans met the performance objective of 99.9% reduction in the combustible mass of the burned charges. Even in

the case of the CGMI tests, where a heavy rain occurred as the charges were burning, the mass reduction was over 99.9%. We did have problems when the propellant charges were soaked (Fig. 11). Burning additional loads of dry propellant on top of these residues should reduce this combustible mass.

Figure 11. Wet propellant (12-0 kg burn) and dry propellant (460 kg) burn residues

6.3 Reduction in mass of energetics

The performance objective for the reduction in the mass of energetics is <0.01% of the original mass of propellants recovered outside the pan. This value applies to both pans. Results and an assessment appear in Table 18.

Table 18. Reduction in the mass of energetics for various models of the burn pan[1]

Burn Pan	Test Location[2]	Total Mass Burned[3]	Recovered Propellant	Assessment
ATU	DRDC	39 kg	<0.01%	ER-1481: Met objective
ATU	FRA	6.3 kg	0.08%	ER-1481: Slightly under objective
ATU	CGMI	12 kg	<0.01%[4]	Exceeded objective. Heavy rain during testing
MTU	FIG	0.32 kg	<0.01%[4]	Exceeded objective
ATU	DTA	46 kg	<0.01%[4]	Exceeded objective

[1] As measured by energetics recovered outside of pan

[2] See Table 16

[3] Mass of analyte in charges

[4] There was not significant difference between pre- and post-burn concentrations of energetics in the soils

No objective was in the scope of work for energetics remaining in the pan after a burn. However, we did measure the energetics in the ash for most of the tests. The results are displayed in **Table 19**. Repeated burns in the pan without cleaning out the ash will likely improve the efficiency of the pan by re-exposing any unburned propellant to another round of intense heat. An over-accumulation of residues, however, may insulate residual propellant from further burning. The pan residues analyses are useful in that the results can be combined with the ejected energetics data to get a better indication of the burn pan efficiency. Also, hazardous waste regulations often apply only to waste that contains at least 10% of the analyte in question. If the concentration of the energetics in the ash is below 10%, it may not be required to treat it as hazardous waste. This will be up to the facility. All tests with measured pan residues had an energetics concentration of less than 0.5% (0.01% – 0.44%).

Table 19. Recovery of energetics from the post-burn residues in the burn pan

Burn Pan	Test Location[1]	Total Mass Burned[2]	Recovered Energetics[3]	Assessment
ATU	DRDC	39 kg	0.83g / 0.002%	ER-1481: Overall efficiency of >99.99%[4]
ATU	FRA	6.3 kg	—	ER-1481: Residues not collected
ATU	CGMI	12 kg	1.5g / 0.01%	99.99% overall efficiency
MTU	FIG	0.32 kg	0.004g / .001%	>99.99% overall efficiency
ATU	DTA	46 kg	0.33g / 0.0008%	>99.999% overall efficiency

[1] See Table 16

[2] Mass of analyte in charges

[3] Percent of the original mass of energetics compared to recovered from soils and following combustible mass analysis

[4] Derived by combining total energetics recovered

Overall Assessment: Both burn pans were highly successful in meeting the critical performance objective of 99.99% reduction in the combustible mass of the burned charges. Energetics within the residues after the burn(s) were also quite low, allowing safe transport and disposal of the ash.

6.4 Unit mass

The performance objective for the burn capacity is 130 kg for the ATU full-sized pan with no component exceeding 70 kg. For the smaller MTU pan, the objective was 80 kg with no component exceeding 50 kg. There are in-

consistencies between the accepted proposal (130 kg) and the demonstration plan (120 kg) as to the target mass of the ATU. I used the proposal figure as a target with the 120 kg mass as a goal. Results and an assessment appear in **Table 20**.

Table 20. Unit mass data for all models of the burn pan

Burn Pan	Test Unit[1]	Total Mass[2]	Heaviest Component[3]	Assessment
ATU	DRDC	210 kg	Base: 113 kg	ER-1481: Overall efficiency of >99.99%
ATU	FRA	127 kg	Base: 49 kg	ER-1481: Residues not collected
ATU	CGMI	115 kg	Base: 46 kg	99.99% overall efficiency
MTU	FIG	79 kg	Base: 29 kg	>99.99% overall efficiency
ATU	DTA	119 kg[4]	Bottom: 43 kg	>99.999% overall efficiency

[1] See Table 16

[2]Empty complete unit without any storage materiel attached

[3]Components consist of the base pan, the false bottom located within the base pan, and the top (bonnet)

[4] Tested mass was 128 kg. Post-test design modifications (final design) brought the mass down to 120 kg

Figure 12 depicts the final burn pan design. The base and perforated bonnet are clearly visible. The false bottom is located inside the base. The base is constructed of aluminum. The false bottom and bonnet are constructed of stainless steel. Hardware and loose parts were kept to a minimum to reduce costs, simplify the design, and increase its robustness.

Figure 12. Final burn pan (ATU).

Overall Assessment: Both burn pans were highly met their mass performance objectives. The ATU final design weighed 120 kg, meeting the more stringent Demonstration Plan goal, and the MTU weighed 80 kg. All components were below the mass limitations set in the project proposal.

6.5 Containment of heavy metals

Determination of heavy metals retention was the most difficult objective to measure. The only test that processed charges containing lead de-coppering foil strips (13g each) was the first test in Canada under ER-1481. The lead was collected in shallow pans outside the burn pan and from the collected residues inside the burn pan. Much lead was observed adhered to the grating in the bonnet, along the sides of the base of the pan, and to the false bottom, making an accurate assessment of lead remaining within the pan too difficult to conduct.

All other tests utilized charges that contained no lead foil. Lead carbonate ($PbCO_3$) is a component of M1 howitzer propellant, and soils surrounding the burn pan were tested to determine if there was an increase in lead as a result of burning the 460 kg of charges. A total of approximately 3 kg of lead was contained within the mass of charges burned for the test and

demonstration at DTA, where we checked the soil for contamination from $PbCO_3$. See **Table 21**.

Table 21. Recovery of Pb from soil samples collected outside the burn pan

Burn Pan	Test Unit[1]	Est. Original Mass of Pb	Lead Recovered[3]	Assessment
ATU	DRDC	3.3 kg[2]	320g / 9.7%	ER-1481: Meets goal of <10% deposition
ATU	FRA	–	–	ER-1481: No measurement
ATU	CGMI	–	–	No measurement
MTU	FIG	–	–	No measurement
ATU	DTA	3 kg[4]	None detected	No significant deposition outside pan

[1] See Table 16

[2] Estimated mass of lead foil in charges

[3] Outside of burn pan only

[4] From $PbCO_3$ in propellant formulation

Overall Assessment: The burn pan appears to be able to contain the lead from within the propellant and the lead foil contained in some howitzer propellant charges. Research conducted by Defence Research and Development Canada–Valcartier indicates that, based on 24 tests, lead deposition outside the burn pan can vary significantly, from under 10% to up to 60%, depending on the burn conditions **[34]**.

6.6 Turnaround time

The performance objective for the turnaround time is 12 min for both units. Turnaround is defined as the time between loading of the pan. Results and an assessment appear in **Table 22**.

Table 22. Turnaround times for the various burn pans

Burn Pan	Test Unit[1]	Number of Tests	Turnaround Time[3, 4]	Assessment
ATU	DRDC	4[2]	15 min	ER-1481: Meets goal of <10% deposition
ATU	FRA	1	–	ER-1481: No measurement
ATU	CGMI	1	10 min	Met objective
MTU	FIG	1	8 min	Met objective
ATU	DTA	6	12 min	Met objective

[1] See Table 16

[2] Estimated. Tests were conducted in conjunction with fixed burn pan tests.

[3] Cool down to approximately 30°C

[4] All times were obtained while training troops on the use of the pan

Times were obtained with a stopwatch or from time stamps on camera footage or the datalogger recording the temperature from thermocouples. An example of data obtained from thermocouples mounted to a burn pan is given in **Fig. 13**. For the DTA tests, output from an IR camera was used to determine the pan temperature and elapsed times (**Fig. 14**). In all cases, we approached the pan within 2 min of the cessation of visual burning, and there was no burning of combustible materials within the pan.

Cool-down temperatures will depend heavily on the ambient temperature and wind conditions, with a cold, windy day resulting in more rapid cool-down times. Areas of the bonnet, which needed to be removed to load the pan, were hot to the touch, so gloves are recommended when using the pan. This is a good idea when handling propellant, so it is not an additional requirement for use of the pan.

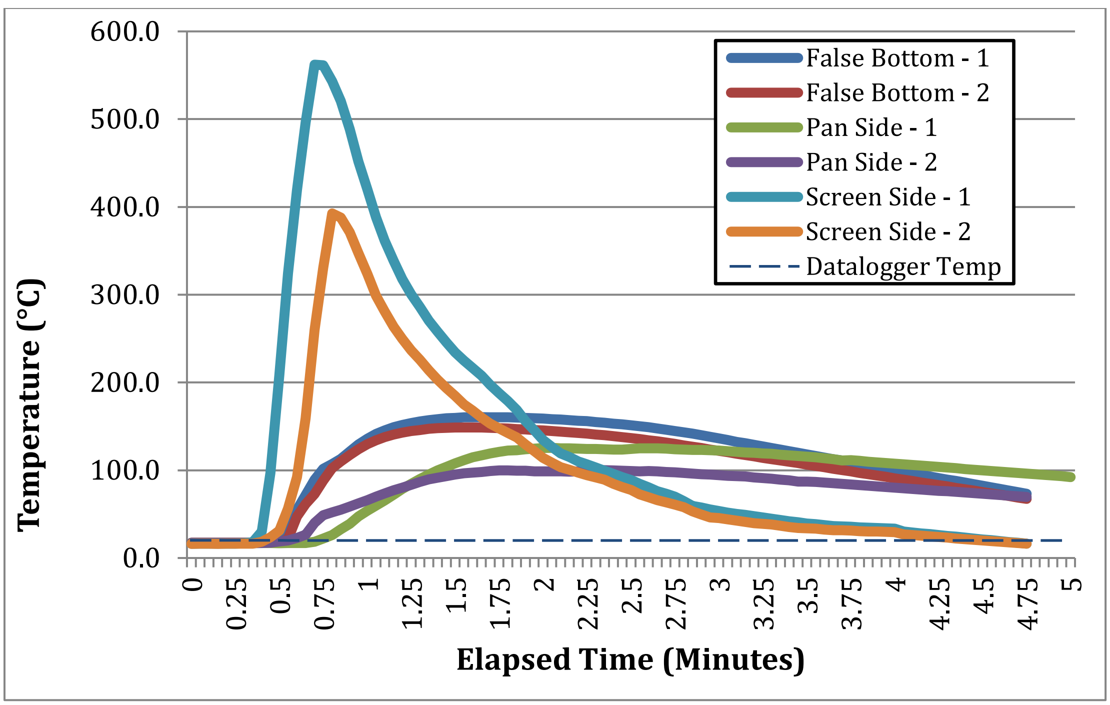


Figure 13. Graph of component temperatures during an ATU burn pan test

Figure 14. IR Camera thermal image 30 seconds after a test burn

Overall Assessment: The turnover time objectives were met for both units. Times will vary depending on ambient temperature and climatic conditions.

6.7 Integration of burn pan into training

This objective was met with enthusiasm by all facility participants with the exception of a commander of an artillery brigade in Alaska. Although the Battery commander was very interested in the pan, the Brigade commander was completely opposed to it. His replacement, with whom we trained three years later, embraced the concept, watching his troops train and requesting access to the pan for further training during the remainder of the exercise (**Fig. 15**). It was clear to most of the officers that the pan provided an excellent training opportunity for their troops. The Army National Guard has adopted the use of the burn pan as a Best Management Practice for all their facilities training with indirect fire weapon systems (howitzers and mortars).

Figure 15. Commander and command sergeant major of the Ohio Army National Guard 1/134th Artillery Battalion prior to first test of burn pan at Camp Grayling, MI

Overall Assessment: The pan has met with general enthusiastic acceptance by the military at sites where the equipment was tested. There will be officers that will not accept the pan based on their attitude towards the environment, but this resistance can be overcome through range policy such as that set by the Army National Guard.

6.8 Ease of use

Operation of the burn pan is straightforward. The two most important precautions are to not overload the pan and to not load the pan before all the residue is extinguished. At DTA, we trained one crew of two soldiers in the pan's use and they rotated one new person in for each of the next five burns. On the last burn, we only observed and provided no assistance. A Users' Manual has been provided to ESTCP that will accompany each pan [35].

Overall Assessment: The pan has met with general enthusiastic acceptance by the military at sites where the equipment was tested. There will be officers that will not accept the pan based on their attitude towards

the environment, but this can be overcome through range policy such as that set by the Army National Guard.

Figure 16. Volunteers of the 2/377th PFAR receiving a briefing on the theory and operation of the CRREL portable burn pan, Donnelly Training Area, AK

Overall Assessment: The soldiers associated with artillery training that volunteered to assist in the testing were all very interested in the burn pan concept (**Fig. 16**). They all quickly learned how to use the system, why the pan was necessary, and how it could improve their training experience.

6.9 Environmental and range control acceptance

Range and environmental managers at all three facilities where the pans were tested stated that the use of the burn pans was a very good idea. Personnel queried included range managers, facility environmental managers, and a member of the DoD's Integrated Training Area Management program.

Overall Assessment: This goal was achieved at all three installations where the pan was tested. It is recommended that a follow-up assessment be conducted to determine overall integration.

7.0 Cost Assessment

The cost of the burn pan is highly dependent on the number built. Currently, the only units built have been in the instrument shop at CRREL. Materials cost is about $1.7K and labor was $6.5K, for a total of $8.2K. Series production at a larger sheet-metal fabrication shop will likely bring the costs closer to $6K to $7K. The cost to conduct the burn is nothing, as the troops will burn the material on site. The only cost incurred by them is the pick up and return of the pan. This compares to several potential trips to a fixed burn facility and the cost of a supervised burn at that site. The burn residues may have to be collected for processing whether the burns occur in a fixed or portable pan. The alternative to burning in a structure, burning on the ground, is not an option at many bases and may incur a future environmental cleanup liability that can easily run into the millions of dollars.

7.1 Cost model

This technology is not complicated. It simply involves a well designed, effective piece of training equipment that is simple to use, easy to clean, and portable. Costs are limited to the initial cost of the burn pan and supporting equipment, maintenance costs, storage of the equipment, and disposal costs, if any. Site characterization may be considered if the pan is regularly used in the same location, but this is unlikely to be a requirement because of the portability of the pan. Most of these costs are not new for well-maintained ranges. Disposal costs should be lower (if they occur) because they will involve only material of known composition. Training on the system is easy, with a Users' Manual available for the range, environmental, and military communities. A cost model is outlined in **Table 23**.

Table 23. Cost model for the CRREL portable burn pan

Cost Element	Data to be Tracked	Costs
Acquisition of burn pan	Cost of materials and labor	Materials: $1.7K Labor: $6.5K
Maintenance costs	Personnel required and associated labor Tools and supplies for maintenance	Labor: $1K/yr
Storage	Facility cost	$1K/yr
Waste disposal	Tools and supplies for residues collection Waste disposal costs	$0.3K Not applicable based on energetics concentration in residues
Site characterization (sampling and analysis)	Personnel required and associated labor Tools and consumable items need for sample collection Shipment costs Sample processing and analytical costs	Not applicable because of portablitiy of the system. If required by facility, costs will be approximately $60K/site.

7.2 Cost drivers

The largest driver for this technology is the potential environmental liabilities resulting from soil and groundwater groundwater contamination. The environmental management and leagal staff of the facility will need to determine two things: If the potential sites where propellant burns are to occur will need baseline and periodic characterization for propellant contamination and whether the collected residues from the burn pan will require analysis and/or disposal as hazardous waste. Results of research conducted through SERDP and ESTCP indicates that neither of these actions will be necessary. However, several installations currently have energetic compounds from propellants in surface and ground water, so additional precautions may be stipulated. These costs will not be additional to the burn pan as they are likely to be occurring at installations where this contamination has occurred. The burn pan may help eliminate these substantial costs through the highly efficient burning during training.

7.3 Cost analysis

Costs associated with the operation of the CRREL Portable Burn Pan system are minimal. Labor is provided by the training soldiers. Maintenance should be minimal, amounting to cleaning out the residues after each

training exercise and repairing any component damaged due to mishandling or use. Transport can be handled by Range personnel (to ensure proper siting) or the training personnel under Range's supervision. Storage will require a simple structure, such as a small shed or a 6 m shipping container, neither of which will require utilities.

Siting of the burn pan will depend on two factors. First, the pan will need to be in an easily accessible location that will not have combustible material nearby, such as tall dry grass, bushes, or trees. Second, it will need to be in proximity to the firing points at which the artillery will be located during training. This will allow quick, easy access for the troops, minimizing transport time to the burn site. It is unlikely that a site will need to be prepared for the pan. A parking lot or section of a firing point will likely suffice.

The cost analysis assumes that there will not be any need for treating the burn residues as hazardous waste. This eliminates the need for site characterization for the locations at which the burn pan may be located as well as the need to ship the residues off site for analysis and disposal. The exception to this is the use of propellants with lead foil decoppering agent. If charges containing the lead foil are burned, the residues will likely have to be treated as hazardous waste because of the presence of heavy metals.

Life cycle costs for the burn pan system will be minimal. The life of a pan will depend on the frequency and magnitude of usage, capability of the facility to affect repairs, and handling of the system. Using the single payment method and a lifetime of 10 years, the present worth of a burn pan with a capital cost of $8000 and a discount rate of 1% will be around $21K, or $2.1K/yr. Add yearly maintenance (≈$0.7K/yr) and storage (≈$0.5K/yr) costs and yearly operating costs come to about $3.5K per year.

There is no remediation that occurs when using the burn pan. The objective of the burn pan is to prevent contamination, thus preventing the future liabilities associated with remediation of contaminated soil or water.

7.3.1 Acquisition

The cost of a pan is currently $8.2K on a single-unit basis. A facility may chose to fabricate their own pan or pans locally or on base at a shop of their own. The cost of a fixed pan is $22K in a production run of 25 units

(S. Thiboutot, DRDC-Valcartier: Personal communication). An installed fixed burn pan will require the additional cost of site preparation, the site itself, and likely the cost of a large concrete pad.

7.3.2 Maintenance

Maintenance costs should be minimal, as the residues will be removed following each training exercise by the trainees. A yearly one-day maintenance is anticipated. For a skilled worker at $80/hr over eight hours, costs will be around $700.

7.3.3 Storage

The unit will need to be stored under cover to ensure availability and reduce weathering. An open shed can be built for a cost of <$1000 if no storage space is available on the facility.

7.3.4 Waste disposal

The cost of waste disposal is unknown at this time as it is dependent on local disposal costs, the extent of training, and the types of munitions used. Some simple tools and supplies will be required to collect the residues from the pan following burn activities. However, the costs will be no more than those resulting from the disposal of waste from a fixed burn pan. There is no up-front cost for waste from expedient burning of propellants on the ground, but future liabilities can easily exceed $100K if soil removal and treatment is required and could run into the millions of dollars if groundwater contamination occurs. The cost of improper disposal of munitions constituents at the Massachusetts Military Reservation currently exceed $1.5B, with many years of remediation remaining.

7.3.5 Periodic site sampling

Periodic site sampling at firing points may be required by landowners or as part of the facility range management agreement. This will occur whichever burn method is chosen, thus the use of the portable burn pan will not incur any additional cost for this factor.

8.0 Implementation Issues

The CRREL Portable Burn Pan system is a cost-effective technology that will accomplish many critical goals at minimal cost. From ESTCP's perspective, the pan is an excellent tool for addressing the environmental impacts that occur with inefficient fixed burn pans or burning of propellant on the ground. For the facility environmental officer, these factors are important as are the ability to minimize the environmental impact of training with live munitions on ranges. Propellant burn residues are also easily collected, making hazardous waste disposal, if necessary, much easier than soil removal, the alternative for heavily contaminated areas. For the range managers, range sustainability is a factor as well, with reduced environmental impacts of training with propellant burns increasing the sustainability of the ranges. The pan also provides a way for Range to control how and where propellant burn training occurs. And finally, for the troops and their officers, the burn pan allows increased training opportunities in a much safer, controlled environment than is currently available.

This being said, we have encountered resistance to the implementation of the burn pan. One facility environmental manager said that if the residues are easy to collect, he will have to collect them and pay for their disposal. He would rather take his chances with groundwater contamination than have to deal with the paperwork. An artillery battalion commander labeled us as "radical environmentalists" interfering with the training of his men and would not allow them to participate in the test. There is a strong anti-environment streak in many of the older military officers that will be a hurdle to overcome. Mandated use through doctrine or range policy may be the only way to avoid tis intransigence.

These are isolated incidences. The Range manager at the base with the resisting Environmental manager wants the burn pan used on his ranges. He sees their value in avoiding restrictions or even loss of training area. He oversees the Eagle River Flats impact range and knows how contamination can cripple training for soldiers. The replacement commander for the colonel who refused to participate in the tests fully accepted the use of the burn pan, requesting access to it for the duration of his unit's training.

The burn pan is a training device, not a disposal system. Thus, environmental regulations that apply to the disposal of hazardous waste do not apply.

Often, simple exposure to the burn pan concept is sufficient to convince responsible parties of the usefulness of the system. To see soldiers quickly learn and understand the concepts of the system and to see the pan in use are impressive events that quickly convert most skeptics. Briefings to senior officials have assisted in the promulgation of the burn pan. It was after a SERDP/ESTCP briefing that the Army National Guard Bureau pushed for implementation of the burn pan as a Best Management Practice on facilities containing indirect fire ranges.

All materials used for the burn pan fabrication are readily available. Raw stock can be purchased from almost any metal vendors. There are few hardware items. These are standard items from industrial suppliers. There should be no problems for most installations to fabricate or contract out the fabrication of a burn pan.

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Appendix A: Points of Contact

Below is a partial list of personnel involved with testing of the burn pan. Unfortunately, most of my contacts have either retired or passed away.

Table A-1. PoCs

POINT OF CONTACT	ORGANIZATION	Phone & E-mail	Role in Project
Dr. Bonnie Packer	USARNG Bureau	(703) 607-7977 bonnie.m.packer.ctr@mail.mil	Proponent – ARNG
Mr. Steve Thurmond	US Army Alaska Range Control	(907) 873-1447 steven.b.thurmond.civ@mail.mil	Proponent – USARAK Range
Ms. Ellen Clark	ITAM: Donnelly Training Area	(907) 873-1614 ellen.m.clark@mail.mil	ITAM Coordinator-DTA

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Appendix B: Calibration of Analytical Equipment

The following is excerpted from the Donnelly Training Area burn pan test and demonstration test report [22]. The same procedures were used in all burn pan tests.

Laboratory control spikes: Two laboratory control spikes were run in a blank soil (Lebanon landfill sand), with a target concentration of 1 mg/kg of 2,4-DNT and 2,6-DNT. Recovery rates following extraction and analysis are shown in **Table B-1**.

Table B-1. Results of laboratory control samples

Sample	2,4-DNT (mg/kg)	% Recovery	2,6-DNT (mg/kg)	% Recovery
LCS-1	0.99	99%	0.97	97%
LCS-2	0.99	99%	0.99	99%

Matrix spikes (Recovery): A matrix spike was conducted on one of the samples (15FPSally-07: See Table C-2 below). The mean concentration prior to spiking was 3.26 mg/kg 2,4-DNT. Based on seven replicates, the 95% confidence limit for this mean is ±0.24 mg/kg. Therefore, the target concentration of the matrix spike ranges from 4.0 to 4.5 mg/kg. Duplicate samples were analyzed and were found to be within the 95% confidence range, indicating 100% recovery (**Table B-2**).

Table B-2. Results of matrix spike samples

Sample	2,4-DNT (mg/kg)	2,6-DNT (mg/kg)
15FPSally-07 (7 reps)	3.26	0.12
15FPSally-07Spike-a*	4.23	1.12
15FPSally-07Spike-b*	4.25	1.13

*Duplicate samples from 15FPSally-07

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Appendix C: Quality Assurance Sampling

The following is excerpted from the Donnelly Training Area burn pan test and demonstration test report [22]. The same procedures were used in all burn pan tests.

Sampling replication: Although not part of the analytical calibration procedure, sample replication is a useful way to assess analytical performance. For our tests, at least three replicates were taken from each decision unit. If large variability occurred between replicates, the samples were rerun or run on a different instrument. Replicate analyses did not reveal any inconsistencies with the analytical instrumentation.

Carryover from sample preparation: Three blank samples were ground consisting of 500g of Ottawa sand (Ottawa, IL, USA) each. One was done prior to grinding the field samples, one half way through the samples, and one after all the field samples were completed. No DNT was found in any of the samples upon analysis.

Soil blank: A 10-g soil blank was run using Lebanon (NH) landfill sand, which we use as a standard soil for extraction blanks. No analytes were detected after extraction and analysis.

Sampling consistency: We did an analysis of the mass per increment (mass/incr.) of soil collected by the various sampling teams. We had not looked at this statistic before and felt it may be useful in gauging the consistency between sampling teams. This is important because uniform increments are necessary to reduce the sampling error. Little variability is found between samples by the same sampler and between samplers (**Table C-1**). The means and medians for both sets of samples match, indicating normally distributed data. Both the standard deviations (STD DEV) and the relative standard deviations (RSD) for both data sets are low.

Table C-1. Mass per increment for soil samples taken around burn pan

Sample	Sampler	Mass/Incr (g)	Sample	Sampler	Mass/Incr (g)
0-3 m DU			3-6 m DU		
15FPSally-01	MRW	18	15FPSally-04	CES	16
15FPSally-02	MFB	19	15FPSally-05	SLJ	16
15FPSally-03	SAB	21	15FPSally-06	SLJ	17
15FPSally-07	SAB	20	15FPSally-10	CES	15
15FPSally-08	MRW	20	15FPSally-11	CES	15
15FPSally-09	MRW	19	15FPSally-12	SLJ	16
	Mean	20		Mean	16
	Median	20		Median	16
	STD DEV	1.1		STD DEV	0.73
	RSD	5%		RSD	5%

The average mass per increment for the 0–3 m DU samples ranged from 18 g/ incr. to 21 g / incr., with a mean value of 20 g/incr., a median value of 20 g/incr., and a relative standard deviation (RSD) of 5%. If mean values are the same as median values, the data are usually normally distributed. For the 3–6 m DU, the range of values was 15 to 17 g/incr. with a mean of 16 g/incr., a median of 16 g/incr., and RSD of 5%. Again, indications are that the data are normally distributed. For soil that is non-uniform both in composition and density, the values depicted in **Table C-1** are quite good.

<u>Replicate analysis of ground soil samples:</u> Replicate subsamples were taken from two of the ground field samples and analyses preformed. Triplicate analyses were performed on a pre-burn sample (15FPSally-03). The 2,4-DNT concentrations for these replicates range from 3.1 to 3.7 mg/kg with a mean concentration of 3.5 mg/kg. For 2,6-DNT, the range is 0.10 to 0.12 mg/kg with a mean of 0.11 mg/kg. The RSD is 9% for the 2,4-DNT and 9% for the 2,6-DNT. Seven subsamples were taken from the sample on which the matrix spike was performed (15FPSally-07). For 2,4-DNT, the concentrations ranged from 3.0 to 3.7 mg/kg with a mean concentration of 3.3 mg/kg and a median concentration of 3.2 mg/kg. For 2,6-DNT, the range is 0.10 to 0.14 mg/kg with a mean and median value of 0.12 mg/kg. The RSD is 8% for the 2,4-DNT and 13% for the 2,6-DNT. **Table C-2** summarizes this data.

Table C-2. Results of laboratory control samples

Sample	Subsamples	2,4-DNT (mg/kg)	2,6-DNT (mg/kg)
15FPSally-03 (Pre-burn 0-3 m)	3	3.7	0.12
		3.1	0.10
		3.6	0.11
	Mean	3.5	0.11
	STD DEV	0.31	0.01
	RSD	9%	9%
15FPSally-07 (Post-burn 0-3 m)	7	3.0	0.13
		3.2	0.14
		3.7	0.14
		3.2	0.11
		3.4	0.11
		3.5	0.13
		3.0	0.10
	Mean	3.26	0.12
	STD DEV	0.26	0.02
	RSD	8%	13%

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Appendix D: Decontamination Procedures

Sampling tools were rinsed with filtered water to remove all soils between replicate samples in the same decision unit. At the end of sampling of each decision unit, the tools were rinsed clean with water then rinsed again with acetonitrile (AcN) and wiped down with a clean paper towel (TechWipe).

Samples were bagged in laboratory-clean polyethylene bags, then double bagged prior to transportation and storage to prevent any cross contamination from the exterior of the bag.

Grinding equipment was cleaned with filtered water, rinsed with can, and wiped clean with TechWipes prior to grinding a new sample. The same procedure was applied to laboratory subsampling tools.

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Appendix E: Sample Documentation

E.1 Field

Field samples were labeled in duplicate and logged into a field book (**Figure E-1**). Each sample bag was labeled with the following information:

- Date
- Field sample number (Year, location, sample number, i.e. 15FPSally01 for 2015 (Year), FPSally (Firing Point Sally, location of sample decision unit), 01 (sample number).
- Type of sample (Pre- or Post-burn)
- Sampled area (0-3 m annulus or 3-6 m annulus)
- Number of increments in the sample
- Sample replicate number (i.e. 1/3: Rep 1 of 3 replicates)
- Samplers' initials (teams of two – first initials are sampler's, second initials the bagger)
- Time of sample completion

Figure E-1. Labeling of field samples.

The same data was written on the plastic tag, which was attached to the top of the sample bag when it was cinched closed with a wire tie.

E.2 Laboratory

The plastic labels from the sample bags were used to rack the samples within the lab. The ground samples were returned to their respective bags after subsampling. Subsamples were tracked by the Field Sample Number from extraction through analysis.

E.3 Chain of Custody

Samples were within our possession except when shipped from Alaska. The containers with the samples were locked, banded, and sealed with tape for shipment.

Appendix F: Photographic Description of a Test Burn

The following is a sequence of images acquired during the demonstration of the CRREL Portable Burn Pan training device at Donnelly Training Area, AK, in August 2015.

Figure F-1. Burn pan test location at Firing Point Sally, DTA, Alaska.

Figure F-2. Briefing of NCOs and enlisted men on theory and operation of the pan.

Figure F-3. Collecting excess 105-mm artillery propellant for burn pan tests and demonstration (not part of a typical propellant burn training exercise).

Figure F-4. Loading burn pan with excess artillery propellant following a previous burn.

Figure F-5. Evenly spreading out charge bags in burn pan.

Figure F-6. Cutting open charge bags to load initiation slider and prime the main burn. Loose propellant grains burn slower, allowing time to go to a safe area after initiation. They are also needed to transition the initiation to the charge bags and the main burn.

Figure F-7. Placing the bonnet on the base of the pan in preparation of initiation.

Figure F-8. Propellant grains in initiation slider.

Figure F-9. Final inspection prior to initiation. The bonnet should be in full contact with the top of the base of the pan and no propellant bags should be outside of the false bottom.

Figure F-10. Initiating the propellant grains in the slider. A charcoal grill lighter is being used in this case.

Figure F-11. Burn sequence of an 89 kg load in the burn pan.

Figure F-11 (cont.). Burn sequence of an 89 kg load in the burn pan.

Figure F-12. Post burn inspection of burn pan at the end of the tests and demonstration. A total of 458 kg of M1 single-base propellant was burned in six tests.

Figure F-13. Damage to burn pan bonnet. A single spot weld broke on the bonnet during testing. The Range Inspector (Joe Clark) determined that the damage was minor and would be easily repaired using in-house resources.

Figure F-14. Post-test residues – false bottom. Total mass of the recovered residues was 41 g.

Figure F-15. Post-test residues – bottom of the base of the burn pan. Total mass recovered was 53 g.

Figure F-16. Post-test wrap-up. Discussions are being held with the ITAM site coordinator (Ellen Clark) while the officers and senior NCOs of the 2/237 PFAR wait for a debrief. LTC Luper and CSM McQueen of the 2/237th both requested their unit be allowed to continue use of the burn pan for training while they were deployed at DTA. Mr. Steve Thurmond, Range Manger at DTA, requested two more pans for his facility. One has been completed and is awaiting the transfer of funds before shipping.

Appendix G: User Feedback

The following is a compendium of the user feedback we received from the various parties participating in the three tests and demonstrations conducted under ESTCP ER-201323. The feedback is grouped by the test venue. This feedback is included as it was invaluable in the progress of the pan design to its final iteration.

Camp Grayling, MI (Artillery Training Unit, 2013)

The following is feedback obtained at CGMI from the interested parties as well as some observations from the CRREL test staff.

- **CGMI Environmental Manager (Mr. John Hunt)**
  - Liked the concept very much
  - Small size and portability are assets
  - Will control and require the use for all indirect fire training utilizing propellant charges.
  - Would like to obtain more burn pans or drawings so more can be built
  - Will cancel requirement for an additional fixed burn pan at CGMI
- **Range Officer (SSG Shaun Regier)**
  - Concept seemed to work quite well
  - Need to locate the burn pan in an area of no vegetation
  - Will need to issue fire suppression equipment with the burn pan
- **Training Unit (1/134th OH ARNG)**
  - An additional set of lifting handles at midpoint of pan would be convenient
  - Liked perforated sides on false bottom, used as loading guides
  - Appreciated the ability to burn propellant on site
  - Saw the presence of the burn pan as a great training opportunity for the soldiers
  - Quite comfortable with using the pan after minimal training
  - Felt that using the pan would increase training efficiency
  - Requested the burn pan remain so they could use it for the two batteries over the course of their training at CGMI

Other Possible Improvements (CRREL)

- Replace removable legs with permanent legs

- Put drain holes with plugs in bottom corners of pan
- Thin stainless angle on top of bonnet to reduce sharp edges
- Install lift handles on bonnet

After-action Tasks (CRREL)

- Modify drawings with changes
- Send a set of drawings to Mr. Hunt

Fort Indiantown Gap, PA (Mortar Training Unit, 2014)

The following is feedback obtained at FIG from the interested parties as well as some observations from the CRREL test staff.

- **FIG Environmental Project Manager (Ms Jo Anderson)**
  - Liked the concept very much
  - Small size and portability are assets
  - Would like the larger pan as well
  - Need another method of accessing propellant to initiate burn
- **Range Commander (LTC Mike Fluck)**
  - Concept seemed to work quite well
  - Would like to keep pan and utilize it for training
  - Can we get the full-size pan?
- **Training Unit (1/110th IN PA ARNG)**
  - No input
- **Other Possible Improvements (CRREL)**
  - Add a second initiation method to pan that doesn't require using the door
  - Make bonnet larger in area so there is no impediment to flame flow from pan
- **After-action Tasks (CRREL)**
  - Modify drawings with changes
  - Send a set of drawings to Ms Anderson
  - Test report copies to ESTCP, FIG, and ARNG Bureau

Donnelly Training Area, AK (Artillery Training Unit, 2015)

The following is feedback obtained at DTA from the interested parties as well as some observations from the CRREL test staff.

- **USARAK ITAM Manager (Ellen Clark)**
  - Liked the concept very much
  - Should be integrated into range management practices
- **Range Commander (Steve Thurmond)**
  - Concept seems to work quite well
  - Would like to keep pan and utilize it for training
  - Would like at least two more additional pans
- **Training Unit (2/377th PFAR)**
  - Handles on bonnet need to be lower for short guys
  - Really like the ability to burn propellant close to firing points
  - Need to reduce the sides of the false bottom to avoid overloading the pan

Other Possible Improvements (CRREL)

- Don't need the door on the bonnet any more – remove from next iteration
- Beef up the mounting of the legs on the base

After-action Tasks (CRREL)

- Modify drawings with changes
- Send a set of drawings to interested parties

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14. ABSTRACT
Munitions for indirect fire weapon systems are issued with a full complement of propellant charges. Excess charges are typically not turned in and are destroyed by open burning as part of the unit's training. Burning of the charges can result in up to 20% of the propellant remaining in the form of residues on the ground. A portable propellant burn pan system was design and demonstrated as part of Environmental Security Technology Certification Program (ESTCP) Project ER-201323 to enable safe, environmentally effective training of the military. Tests have demonstrated a 99.98% reduction in combustible mass of the charges, less than 0.001% of the energetics in the burn pan ash, energetics concentration of less than 0.5% in the residual ash, and no detectable difference in energetics in the soil surrounding the pan after burning over 450 kg of charges. Performance objectives for the burn pan device were met or exceeded by the final system design. Costs associated with acquisition, implementation, use, and maintenance of the burn pan system are reasonable. The U.S. Army Cold Regions Research and Engineering Laboratory portable propellant burn pan training device has been enthusiastically accepted by all who have participated in the ER-210323 test and demonstration program.

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